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IV. GEOLOGY AND PALEONTOLOGY.

THE DAKOTA CRETACEOUS OF KANSAS AND NEBRASKA.

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INTRODUCTION.

Few geological groups are so widely and yet so superficially known as the Dakota Cretaceous. From the time Lewis and Clarke, in 1804, first noticed the hills of soft, yellow sandstone along the Missouri river at Blackbird hill and Maha (Omaha) creek until the present, there have been papers and references galore to this formation. One of several reasons for this fact may be that it is the only distinctively sandstone group of the plains. All other formations—Paleozoic, Mesozoic, or Cenozoic—consist, chiefly, of limestones, shales, and silt. There are, or course, many ledges of sandstone in the Carboniferous and other groups, but with a few minor exceptions the statement is true.

The group is known, however, chiefly by its fossils. Perhaps no other formation has yielded so large and varied a collection of species. The fossils are, for the most part, plants, particularly dicotyledonous leaves, although both vertebrates and invertebrates are represented. Some of the most famous paleontologists, both phyto and invertebrate, of Europe and America have written concerning this group. The literature is scattered throughout government and state reports, proceedings of scientific societies, bulletins of numerous surveys, and various scientific periodicals, not to mention the polite literature of such authors as Irving and Cooper.

The present paper was undertaken with the intention of presenting a fairly complete description of the Dakota group in the light of the present knowledge of the subject. It was also planned to include descriptions and plates of a num-

ber of new species of plants collected during the field seasons of 1898 and 1899, by Dr. Lester F. Ward and the writer. Before the studies of the leaves were completed, however, Doctor Ward suggested that a monograph of the Dakota group be prepared with such geological discussions as recent investigations demanded, paying particular attention to the new species of plants. After consultation with Dr. Erwin H. Barbour, under whose direction the work was being done, it was decided that while such a work was feasible it was manifestly impossible to complete the entire subject in the limited time allowed. This necessitated a change in the plan of the work. The present paper, therefore, should be considered preliminary in character. The writer is not unmindful that the discussions are in places more in the character of a popular report than of a technical presentation of scientific data. This fact, however, may not necessarily be regarded as an unmixed evil. The work on the monograph along the lines suggested by Doctor Ward is in progress. The writer hopes within a reasonable time to present to the scientific world this contribution to the knowledge of one of our most interesting of geological groups.

In the work of the investigation of the various problems connected with the Dakota, I have had the kindly assistance and suggestion of Dr. Lester F. Ward and Dr. T. W. Stanton, of the United States Geological Survey. In the preparation of this article, I have been especially fortunate in the aid and criticism of Dr. Erwin H. Barbour and Mr. C. A. Fisher, of the University of Nebraska. To each of these gentlemen are due my heartfelt thanks.

HISTORICAL SKETCH.

No attempt has been made to prepare an exhaustive treatment on the history of the Dakota group. The literature is not only considerable but it is also widely scattered. Of the hundreds of articles and references dealing with this group, but a few of the most important will be cited. The subject naturally divides itself into four general heads, which have been somewhat loosely followed in the discussion. The first period, or that of early discovery, begins in 1804, and ends in 1856. The second extends from 1856, when Meek and Hayden began their famous controversy concerning the age of the beds, to 1864, the date of the publication of Mr. Marcou's paper in which he admits the Cretaceous age of the formation. The third period, during which Dr. Leo Lesquereux figured so prominently, began in 1866, and closed with the publication of "The Flora of the Dakota Group" in 1892, after the death of Doctor Lesquereux. The last period deals with the question of invertebrates and recent investigations.

For a more detailed account of the subject the reader is referred to the articles cited in the bibliography at the close of this paper. This bibliography, however, makes no pretensions to completeness.

EARLY DISCOVERIES.

It is to the records of the exploring expedition of Lewis and Clarke, which in 1804 ascended the Missouri river, that we must go for the first mention of the sandstone now known as the Dakota group. Previous to this time French and English traders and trappers had gone up the river, and had even built temporary trading stations along its banks; but these men, interested in pecuniary gain alone, left no record of the natural scenery of the country. The first account of the Lewis and Clarke expedition was published by Patrick Gass, a member of the party, in 1807. Under the date of August 10, 1804, Sergeant Gass says: "We stopped to examine some high yellow banks on the south side and camped on the north side."¹

1. Jour. of Voyages, etc., of Lewis and Clarke, by Patrick Gass, pp. 27-28, 1807.

On the 11th, he speaks of some bluffs of yellow sand that extended for several miles along the river. A more comprehensive account is given in the journal kept by Captain Clarke, as follows: "We halted on the south side for the purpose of examining a spot where one of the great chiefs of the Mahas [Omahas], named Blackbird, was buried. A hill of yellow, soft sandstone rises from the river in bluffs of various heights till it ends in a knoll about 300 feet above the water."²

This was on August 11. The next day the following entry appears, referring to some hills a few miles further up the river: "Four miles beyond this bend a bluff begins and continues for several miles on the south; it rises from 20 to 150 feet, and consists of yellow and brown clay, with soft sandstone embedded in it."³

These three localities are easily recognized to-day. The high banks, first mentioned by Sergeant Gass, are the "High Banks," a mile north of Decatur, Neb. It is a curious coincidence, if nothing more, that the name casually used by Sergeant Gass is the one by which the bluff is now known throughout the region. Blackbird hill is still pointed out to the traveler through the Omaha reservation, and the person who will take the trouble to go up the river a mile above the old mission building will find the "bluff of yellow and brown clay with soft sandstone embedded in it."

The noted geographer, Nicollet, in his journey up the Missouri in 1839, mentions a number of formations, but seems to have confused the Dakota with the underlying Carboniferous. Audubon and Harris, in 1843, Evans, in 1849, and Culbertson, in 1850, were either not interested in geology, or else passed the sandstones of this group with a cursory examination, and devoted their time to the somewhat better-developed beds of the more recent formations further west.⁴

It was in 1853 that the first systematic work was done on the Cretaceous of the Missouri river, of which the Dakota forms the basal member. Dr. F. B. Meek and Dr. F. V. Hayden, men whose names are inseparably connected with the geology of the Northwest, were sent on an expedition to the Bad Lands by Dr. James Hall, of Albany. Although the time was spent chiefly among the later Cretaceous and Tertiary formations, a comprehensive idea of the whole series was obtained. It was during this trip that the first fossil leaves were found in the Dakota.

About this time Prof. Jules Marcou, a French geologist, published a geological map of the United States, in which he colored most of the region west of the Missouri river as Jurassic.⁵

On March 11, 1856, Meek and Hayden read a paper before the Philadelphia Academy of Science, entitled "Descriptions of New Species of Gastropods from the Cretaceous Formations of Nebraska Territory." In a prefatory note they discuss briefly the relations of the formations, and give the following section:

Tertiary.....	400-600 feet.
Cretaceous:	
No. 5. Gray and yellow arenaceous clays, containing great numbers of marine mollusks with a few land plants.....	100-150 "
No. 4. Plastic clay with numerous marine mollusks.....	350 "
No. 3. Gray and yellow calcareous marl containing <i>Ostrea congesta</i> , fish scales, etc.....	100-150 "
No. 2. Grayish and lead-colored clays having a few fossils.....	80 "
No. 1. Sandstone and clays not positively known to belong to the Cretaceous age.....	90 "
Upper Coal Measures, limestone at Council Bluffs. ⁶	

2. Lewis and Clarke's Exp. up Mo. Riv., 1814, 1: 43.

3. Ibid.

4. Meek and Hayden, Proc. Phila. Acad. Sci., 8: 111, 112.

5. Bull. Geol. Soc. of France, 1850.

6. Proc. Phila. Acad. Sci., 8: 63-69.

This is the first draft of the now famous Missouri river section of the Cretaceous. With the publication of this section closes the first period in the history of the Dakota group.

THE MEEK-HAYDEN CONTROVERSY.

About three months after the reading of the article last referred to, Meek and Hayden read another paper, in which they discussed the various members of the Cretaceous, and especially No. 1. The statement is made that Professor Marcou is certainly mistaken in supposing that all the country west of the Missouri river was Jurassic, although they admit that their No. 1 may belong to that age.⁷

During the summer of 1856 these gentlemen again visited the region, and in November of that year published a paper in which the section given above is greatly elaborated. No. 1 is described as follows: "Heavy-bedded, yellowish sandstone, passing downward into alternations of sandstone and clay, containing bits of water-worn lignite and bands of dark carbonaceous matter. This formation is not positively known to belong to the Cretaceous system."

And the locality: "Near the mouth of the Big Sioux river and between there and Council Bluffs."

In the discussion of the various groups, referring to No. 1, they say: "We think it barely possible that these beds may be older than the Cretaceous. . . . If not older than the Cretaceous, we think they probably represent some of the older members of that system."⁸

On May 12, 1857, Doctor Hayden presented to the Philadelphia academy an article entitled "Notes Explanatory of a Map and Section illustrating the Geological Structure of the Country bordering on the Missouri River."⁹ On May 26, Meek and Hayden read an article containing descriptions of fossils, and remarks on the Cretaceous and Tertiary formations of the Northwest.¹⁰ These papers are quite exhaustive in the discussions of the various formations. The latter paper is especially interesting because of the fact that in it a number of comparisons are drawn with the Cretaceous of other portions of the United States. Sections are given from New Jersey, Alabama, Kansas, New Mexico; and the following conclusions reached regarding the basal member:

"There is at the base of the Cretaceous system, at distinctly separated localities in Nebraska, Kansas, Arkansas, New Mexico, Alabama, Texas, and New Jersey, a series of variously colored clays and sandstones of great thickness, in which organic remains, excepting leaves of trees, apparently dicotyledons, fossil wood and obscure casts of shells, are rarely found, but which everywhere presents a uniformity of lithological and other characters pointing to a similarity of physical conditions during their deposition over immense areas. Although the weight of evidence thus far favors the conclusion that this lower series is of the same age of the Lower Greensand or Necoman of the old world, yet we await positive evidence that portions of it may not be older than any part of the Cretaceous system."

By March, 1858, they had advanced yet another step, and, after reviewing the evidence of the dicotyledons in the rocks and the position of the adjacent strata, they say: "We think we hazard little in viewing at least a considerable portion of No. 1 as belonging to the Cretaceous system."

In the meantime Maj. F. Hawn had published a paper in which he referred to the whole of the sandstone formation in Kansas as Trias.¹¹ Doctor Hayden, in a paper before the Philadelphia academy, read July 29, 1858, took exceptions to the conclusions of Major Hawn; and, for apparently the first time, placed the

7. Loc. cit., 8: 111.

8. Proc. Phila. Acad. Sci., 8: 267.

9. Loc. cit., 9: 109-116.

10. Loc. cit., 9: 117-133.

11. Trias in Kansas, St. Louis Acad. Sci., 1: 171.

formation definitely in the Cretaceous. The following is Doctor Hayden's statement:

"The discovery at Blackbird hill during the past year of dicotyledonous leaves allied to the oaks, willows, and others of our deciduous forest-trees, together with their position with regard to other well-known Cretaceous formations, renders the evidence quite clear that a large portion of the strata which we had included in No. 1 of our vertical section is of Lower Cretaceous age. . . . Major Hawn has found the same or similar leaves in the formation in Kansas. . . . We have, therefore, arrived at the conclusion that No. 1, as it is revealed from Council Bluffs to the Big Sioux, is Lower Cretaceous, although two or three beds of yellow or ash-colored clays exposed at low-water mark near Blackbird hill may be Upper Jurassic."¹²

It is interesting to note the extreme slowness with which these distinguished scientists reached their conclusions regarding the age of this formation. Their opinion once formed, however, they never afterward changed it, and the geological world gradually came to accept their position. It was about this time that Meek and Hayden, desiring some paleobotanical evidence on the age of the beds, sent to Prof. Oswald Heer, the distinguished phytopalaeontologist of Zurich, some outline sketches of a few of the plants. Not having heard from him for some months, the entire collection of fossil leaves was submitted to Dr. J. S. Newberry, who, after studying the forms, referred them to thirteen genera, and unhesitatingly placed them in the Cretaceous. This was in November, 1858.¹³

The same year Prof. G. C. Swallow published a paper entitled "Rocks of Kansas."¹⁴ The sections given were made along the Kansas and Smoky Hill rivers, apparently as far west as Ellsworth county. The rocks of the state were divided into five groups, viz.: Quaternary, Cretaceous, Triassic, Permian, and Carboniferous. The Cretaceous rocks included the limestones and shales which are now known as the Fort Benton, and the 420 feet of sandstone and shale between these rocks and the Permian were designated as Triassic (?), although, in a foot-note, the statement is made that the name is only provisional and did not refer to the known age of the rocks.

The Dakota group, or rather the formation which has since received that name, was at this time (1858) considered as Triassic by Swallow and Hawn; as Jurassic by Marcou; and as Cretaceous by Meek, Hayden, and Newberry. To add to the complication of the problem, Meek and Hayden received, on December 15 of this year, a letter from Professor Heer, in which he referred the plants, of which sketches had been sent him, to six genera, and inclined to the opinion that they were of Tertiary age.¹⁵

At the same time Professor Marcou published a paper addressed to "Messrs. F. B. Meek and F. V. Hayden," in which he quotes the conclusions of Professor Heer, and expresses the opinion that No. 1 of the Nebraska section is both Miocene and Jurassic.¹⁶ In other words, he thinks that there are included in this group strata belonging to these two widely separated geological epochs. In their paper read December 21, Meek and Hayden express a high regard for the opinions of Professor Heer, but state that it is impossible for the formation to be Tertiary. They attribute his mistake to the fact that he saw only imperfect sketches of the leaves.¹⁷ Concerning the matter, Doctor Lesquereux afterward said: "From what we know of the character of the Dakota leaves, it is clear that, judging from mere sketches, the celebrated professor of Switzerland could scarcely have come to a different conclusion."¹⁸

12. Proc. Phila. Acad. Sci., 9: 139-157.

13. St. Louis Acad. Sci., 1: 173-175.

14. J. Marcou, Zurich, 1858, 16 pp.

15. Cretaceous Flora, U. S. Geol. Surv. of Terr., 6: 4.

16. Proc. Phila. Acad. Sci., 1858, p. 257.

17. Proc. Phila. Acad. Sci., 1858, pp. 265, 266.

18. Loc. cit., pp. 257, 258.

The papers of Major Hawn and Professor Swallow induced Meek and Hayden to visit Kansas. In the summer of 1858 they ascended the Kansas and Smoky Hill rivers as far as the Smoky Hill buttes. As the result of this trip two articles were published, both in January, 1859. The first was entitled, "On the So-called Triassic Rocks of Kansas."¹⁹ The second, "Geological Explorations in Kansas Territory."²⁰ In the first article, which is rather preliminary in character, the authors discuss the position assumed by themselves and by Major Hawn, and cite the authority of Doctor Newberry with regard to the dicotyledonous leaves to prove the Cretaceous age of the rocks. They admit, however, that the ledge which caps the Smoky Hill buttes may be either Triassic or Jurassic, but they also state that, in the absence of paleontological data, conjectures on this point are futile. One point mentioned in this paper may explain in a measure the confusion into which the discussion had fallen at this time. It is contained in the following lines: "There is no unconformity, as far as our knowledge extends, amongst all the rocks of Nebraska and northeastern Kansas, from the Coal Measures to the top of the most recent Cretaceous."

Had the obvious unconformity between the Permian and the Cretaceous, which has since been observed in numerous localities, been known to these pioneers in western geology, much of this misunderstanding would have been avoided. These men, not knowing that such unconformity existed, were simply trying to read into the geology of the region whole epochs which did not exist, in order to make the sequence correspond to that of European geology.

The second article referred to above deals at length with the formation under discussion. A number of sections are given, the last of which is entitled: "General Section of the Rocks of the Kansas Valley, from the Cretaceous down so as to Include Portions of the Upper Coal Measures." The upper member of this section, taken at the Smoky Hill buttes, is described as follows:

Red, brown, and yellowish, rather coarse-grained sandstone, often obliquely laminated, and containing many ferruginous concretions; also, fossil wood and many leaves of dicotyledonous trees, some of which belong to existing genera and others to genera peculiar to the Cretaceous epoch. 60 feet.

This ledge is one of the most pronounced in the Dakota area. It forms the cap of the Smoky Hill buttes and of Soldier Cap mound, and may be traced for miles along the valley of the Smoky Hill river and its tributaries. The section of Meek and Hayden is not carried so high as that of Swallow, the latter including the Benton limestone, which is exposed about ten miles northwest of this locality. Below this ledge the authors describe 230 feet of sandstones and variously colored clays and shales before reaching the limestones and clays which they rightly consider the upper member of the Permian. Concerning these beds they say: "Between No. 5 (the Upper Permian) and the Cretaceous above (referring to the ledge at the buttes) there is still a rather extensive series of beds in which we found no fossils; they may be Jurassic or Triassic, or both; though, as we have elsewhere suggested, we rather incline to the opinion that they belong to the former age."

From the above it will be seen that Meek and Hayden at this time hesitatingly conceded the possibility of Jurassic beds in Kansas and Nebraska. The Kansas formations have since been demonstrated to belong to the Comanche Cretaceous, and, without further discussion, the beds at Blackbird hill have long been tacitly admitted to be Dakota.

It was at this time that the Heer-Newberry-Lesquereux controversy concern-

19. Am. Jour. Sci., 27: 31-35.

20. Proc. Phila. Acad. Sci., 11: 8-30.

ing the paleobotanical evidence of the age of the Dakota began. It will be remembered that Meek and Hayden had sent drawings of some of the leaves from this group to Professor Heer, who expressed an opinion that they belonged to the Tertiary. Doctor Newberry, however, to whom the leaves themselves had been submitted, considered them Cretaceous. In a letter to Prof. J. D. Dana, published in the *American Journal of Science*, Doctor Lesquereux quotes from Professor Heer, among other things, the following sentences:

"Your views of the flora of North America agree perfectly with what we find in Europe. This leads me to believe that the plants of Nebraska belong to the Tertiary and not to the Cretaceous formation. It is true that I have seen only some drawings which were sent to me by Messrs. Hayden and Meek, but they are all Tertiary types. The supposed *Crednaria* is very like *Populus luce* Ung. of the Lower Miocene; and the *Ettinghausiana* seems hardly rightly determined. Besides, it is a genus badly founded, and has as yet no value. All the other plants mentioned by Doctor Newberry belong to genera that are represented in the Tertiary and not in the Cretaceous. It is very improbable that in America the Cretaceous flora has had the characteristic plants of the Tertiary, and this would be the case if these plants did belong to the Cretaceous."²¹

Doctor Newberry took exception to these statements, and replied at length in a letter dated October 15, 1859, likewise published in the *American Journal of Science*.²² He answered the objections of the Swiss professor in detail, and made the statement, which has since been universally accepted, that the vegetation in Cretaceous times had the same general aspect as that of the present.

Professor Lesquereux replied to this letter with another, in which he defended Professor Heer's statements, and discussed at some length the position of both parties.²³ Doctor Newberry again replied, reiterating his former statements, and answering the criticisms of Professor Lesquereux.²⁴ And finally Professor Heer, in an article published in May, 1861, defended his position, namely, that the plants are Tertiary rather than Cretaceous, if judged from the standpoint of European paleobotany.²⁵ This discussion added little to the settlement of the point at issue, and was at the time regretted by the gentlemen engaged in the controversy. Both Professors Heer and Lesquereux afterward came to accept the position of Doctor Newberry.

Meek and Hayden, in 1861, published a paper in which they in a general way discuss the geology of the entire upper Missouri region. In this paper they finally complete the section of the Cretaceous rocks first published in 1853, and which from time to time had been revised and elaborated. As completed, the section includes 2600 feet of strata, and is divided into the following groups, corresponding to the numbers formerly employed:²⁶

No. 5. Fox Hills beds.....	500 feet.
No. 4. Fort Pierre group.....	700 "
No. 3. Niobrara group.....	200 "
No. 2. Fort Benton group.....	800 "
No. 1. Dakota group.....	400 "

The description of the Dakota group, which for the first time bears that name, and in which we are particularly interested, is as follows: "Yellowish, reddish and occasionally white sandstone, with, at places, alternations of variously colored clays and beds and seams of impure lignite. Also silicified wood and great numbers of leaves of the higher types of dicotyledons; with casts of *Pharella? dakotensis*, *Axinella siouxensis*, and *Cyprina arenaria*."

The description of the locality is: "Hills back of the town of Dakota; also

21. Am. Jour. Sci., 28: 85-89.

23. Ibid., 434-436.

25. Loc. cit., 31: 435-440.

22. Loc. cit., 29: 208-218.

24. Loc. cit., 30: 273-275.

26. Proc. Phila. Acad. Sci., 1862, p. 419.

extensively developed in Dakota county, below the mouth of the Big Sioux river; thence southward into northeastern Kansas and beyond."

In the discussion of the Dakota group they say: "Although we still retain this as a distinct rock, our present impression is that it is only a subdivision or member of the Fort Benton group. Still, until more fossils can be obtained from it in the region of typical localities, the question whether or not it should take rank as a distinct formation must remain an open one. The position of the rock beneath the Benton indicates that it is certainly as old as that group, while the dicotyledonous leaves found in it prove that it cannot be older than the Cretaceous."

In 1863 Professor Marcou, for the first time, visited the Dakota sandstone. He was accompanied by the Italian geologist, Capellini. Collections of leaves were made at Tekamah, Blackbird hill, and at the mouth of the Big Sioux river. Although up to this time Professor Marcou had contended for the Jurassic age of the beds, he was now convinced that they were Cretaceous. In an article published in 1864, "*Une Reconnaissance Géologique au Nebraska*,"²⁷ this was frankly admitted. This practically ended the discussion, and settled one of the long-mooted questions of the geology of the West.

LESQUEREUX'S WORK ON PALEOBOTANY.

It was in 1866 that the descriptions of the leaves collected by Messrs. Marcou and Capellini were published, in a paper entitled "*Les Phyllites Crétacées du Nebraska*."²⁸ The account of the trip and description of localities were written by Professor Capellini, and the leaves were figured and described by Professor Heer. They include seventeen species, all of which are new. The article constitutes the first description of leaves from the Dakota; and from it nearly all the leaves since found in northeastern Nebraska have been identified.

While the age of the Dakota in its type locality, near Sioux City and Blackbird hill, was practically settled by the admission of Professor Marcou, the age of what is now known to be the same rock in Kansas was much longer a matter of doubt. Prof. B. F. Mudge, in 1866, described the finding of a fossil footprint in the Liassic (?), on the Republican river, about fifty miles from its mouth, and stated that the Triassic, Jurassic and Cretaceous were all represented in that part of Kansas.²⁹ Doctor Hayden, in speaking of the beds referred by Major Hawn to the Trias, says: "They may be Trias, Permian, or even Jurassic, as far as any evidence yet obtained goes. . . . We must await further evidence before we can regard the existence of Trias in eastern Kansas as demonstrated."³⁰ In 1869, however, Professor Mudge found marine invertebrates and dicotyledonous leaves in the same beds in Saline county, and referred the disputed formation to the Dakota.

Doctor Newberry published an article in 1868 describing the leaves collected by Meek and Hayden at various times and from various localities in the Dakota.³¹ It was intended that an extended report of the leaves follow this article, and a series of plates was prepared awaiting this report, which was to constitute volume VIII of the Geological Survey of the Territories. The report, however, was never written, and in 1878 Doctor Hayden published a small edition of 500 copies of the plates.³²

Leo Lesquereux, who afterward did more than any other man to further the

27. Soc. Geol. France, Bull., 2e ser., 21: 132-146.

28. Mem. de la Soc. Helvétique des Sci. Nat., 22, No. 1.

29. Am. Jour. Sci., 41: 174-176.

31. Annals Lyc. Nat. Hist. N. Y., 9: 1-76.

32. Illust. of Cret. and Ter. Plants, Washington, 1878, 27 pl.

30. Loc. cit., pp. 32-40.

work of phytopaleontology in America, became interested in the subject about this time. As early as 1856 he had observed fossil leaves in the sandstone near New Ulm, Minn.³³ Again, in 1859, his name appeared as a champion of the Swiss scientist in the Heer-Newberry controversy; but it was not until 1868 that his first contribution to the paleontology of the group appeared. It was entitled "On some Cretaceous Plants from Nebraska,"³⁴ and discusses fifty-three species, forty of which are considered new forms. This paper, published the same year as that of Doctor Newberry, was the first of a series by the same author. The material collected on the various expeditions of Doctor Hayden, as well as that sent from Kansas by Professor Mudge, John Leconte, Charles Sternberg, and others, was described in these reports.

In addition to this, Doctor Lesquereux himself visited the collecting grounds and secured a large number of specimens. He was in Kansas in 1873, and the next year visited both Kansas and Nebraska. The various species mentioned from time to time were figured in his "Cretaceous Flora,"³⁵ published in 1874. This was the most comprehensive report so far published. A short historical sketch is annexed, and the various phases of the Dakota group are discussed with a remarkable clearness and penetration. The views here first set forth are in general still accepted by American paleobotanists. As new material was collected, it was sent to Doctor Lesquereux for identification. This necessitated additional publications, and almost every year brought forth from his facile pen a contribution to paleobotanic literature. In 1876 he published an extended article, in which a number of new forms are described and figured.³⁶ Other articles followed, and in 1883 he published his "Cretaceous and Tertiary Flora," containing nearly 300 pages, accompanied by fifty-nine plates, seventeen of which are devoted to Dakota plants.³⁷ This was the second of the three monumental works on this group by this eminent scientist. During these years many collectors had been at work. Judge E. P. West, Prof. B. F. Mudge, H. C. Towner, Charles Sternberg and others had made extensive collections, especially in Ellsworth county, Kansas, where the Dakota reaches its typical development. The leaves collected were sent to several American universities, notably Harvard, and even to Europe. The largest collections, however, were secured for the University of Kansas and for the Smithsonian Institution. Practically all of these fossils were identified by Doctor Lesquereux, who continued to publish descriptions of the various new forms.

About 1885 he began his final work, a monograph entitled "The Flora of the Dakota Group." The manuscript of this work, containing about 500 written pages, and including descriptions of 350 species, was submitted to the publisher in February, 1888. Before it could be published, however, additional discoveries of leaves were made in Kansas and the specimens sent to Doctor Lesquereux for identification. Although in feeble health, he began the work with his characteristic enthusiasm. Finding much new material, he requested that his manuscript and plates be returned to him, in order that he might incorporate it in the monograph. In a short time he had identified and described 110 new forms, bringing the number of species in the Dakota up to 460. Before the figures were all drawn, however, Doctor Lesquereux died, October 25, 1889. The monograph, edited by Dr. F. H. Knowlton, was published in 1892.³⁸

33. Cret. Flora, p. 6.

34. Am. Jour. Sci., 46: 91-105.

35. Rept. U. S. Geog. Surv. Terr., vol. VI.

36. U. S. Geol. and Geog. Surv. Terr., Bull. No. 1, 2d ser., pp. 233-248.

37. U. S. Geol. and Geog. Surv. Terr., vol. VII.

38. U. S. Geol. Surv., Mon. No. 17.

INVERTEBRATES AND RECENT INVESTIGATIONS.

Another phase of the history of the Dakota group remains to be considered, and that but briefly. It is the question of invertebrates. From almost the first mention of the sandstone by Meek and Hayden the paucity of animal remains was constantly referred to. The overlying Benton was very prolific in shells, as was the subjacent Carboniferous. In the Dakota, on the contrary, few forms were found, and these in restricted localities. In the general section, published in 1870, only three species were mentioned from the Dakota, while the Benton is characterized by fifteen and the Pierre by more than twenty forms. The marine invertebrates referred to above, which were found in Saline county by Professor Mudge, were obtained from the lower part of the group, not many feet above the Permian. The shells were identified by Professor Meek. Other specimens were occasionally found in scattered localities, and were identified from time to time by Dr. C. A. White and others. The last of these descriptions by Doctor White appeared in 1894, and dealt with some shells from near Fairbury, Neb., found a little above the middle of the group.³⁹

Meanwhile the investigations of Hill in Texas and Cragin in southern Kansas had demonstrated the presence of vast beds of Lower Cretaceous rocks in these regions.⁴⁰ In response to the invitation of Prof. A. W. Jones, of Salina, Kan., who had rediscovered the locality first found by Mudge in 1869, Professor Cragin visited Saline county, and in 1895 published a paper, in which he inclines to the opinion that the beds in central Kansas that are found at the base of the Cretaceous represent a northern extension of the Comanche or Lower Cretaceous of the Texas-Oklahoma regions.⁴¹ The position taken by Professor Cragin now has the assent of practically all geologists who have studied the question.

In 1891 Dr. C. A. White published his "Correlation Papers on the Cretaceous," probably the most authoritative utterance so far written on the subject.⁴² The Dakota horizon is regarded as a fresh-water deposit, constituting the basal member of the Upper Cretaceous. At that time, however, the deposit of its strata was not known to have immediately succeeded that of the Lower Cretaceous. These conditions have since been observed in several localities, notably in southern and central Kansas. Doctor White states that the Dakota is so well defined that no difference of opinion as to its identity, characterization and delimitation has ever arisen among geologists who have studied it in the southern interior region, *i. e.*, south of the Platte river. The opinion is also expressed that we must rely almost exclusively upon fossil plants for the paleontological characterization of the horizon.

During the last decade much work of permanent value has been done in the Dakota. Several publications of more than passing interest have appeared, but these must of necessity be passed by in this review. It may not, however, be inadvised to mention the names of Lester F. Ward, Erwin H. Barbour, T. W. Stanton, N. H. Darton, Robert Hay, Charles S. Prosser, J. W. Beede, S. W. Williston, G. K. Gilbert, Geo. I. Adams, C. A. Fisher, W. N. Logan, F. W. Cragin, and A. W. Jones, all of whom have, either directly or indirectly, added to our knowledge of the Dakota Cretaceous of Kansas and Nebraska.

GEOGRAPHICAL DISTRIBUTION.

INTRODUCTION.

It is not the province of this article to discuss the Dakota group beyond the limits of the states of Kansas and Nebraska, except the small area near Sioux City, in northwestern Iowa, and this only because of its early connection with

39. Proc. U. S. Nat. Mus., 17: 131-138.

40. Am. Jour. Sci., 50: 205-234. Also, Am. Geol., 16: 357-385.

41. Am. Geol., 16: 162-165.

42. U. S. Geol. Surv., Bull. No. 82.

the literature of the group. Passing by the exposures which are known to occur in Minnesota, South Dakota, Wyoming, Colorado, Oklahoma, New Mexico and other states, I shall at once proceed to consider the Kansas-Nebraska outcrops of the Dakota.

In general, the formation as exposed in the region extends in a line from Sioux City, Iowa, to Ashland, in southwestern Kansas. The distance as the crow flies is not far from 500 miles. The width of the group, as exposed, probably averages about thirty-five miles, although places may be found where the distance from the eastern to the western limits is to exceed eighty miles. Both the lower and upper lines of outcrop are exceedingly irregular. The subjacent formations extend far up the valleys, and in places approach within a few miles of the Benton, which, resting on the Dakota, caps the hills to the west. A good example of this fact may be seen in western Saline and eastern Ellsworth counties, Kansas. From Brookville, which is near the top of the Permian, to the noted cave section, on the hills back of which the Benton may be found, is less than ten miles, although in the intervening country may be found some of the roughest and most typical Dakota in the two states. Another instance is near the Kansas-Nebraska line. The Permian is found as far up the Little Blue river as Steel City; while the Benton on the hills to the west is not more than six miles distant.

In the following discussion I shall consider that the line of unconformity at the base of the Cretaceous rests, respectively, on three phases of the Upper Paleozoic rocks: Upper Carboniferous, Permian, and Triassic; that the horizons just mentioned are conformable throughout; that the Comanche series, or Lower Cretaceous of Kansas, is found only in the southern and central parts of the state; that it consists of two formations—the Cheyenne sandstone, confined to the Belvidere locality, and the Kiowa shale, known in the central part of the state by the term “Mentor Beds”; that the Dakota rests conformably on the Lower Cretaceous wherever the latter is exposed; and that it passes conformably above into the Benton, which consists of shales and fossiliferous limestones. These topics are treated at greater length under their proper head, stratigraphy, and are introduced here simply in order that the subject may be understandingly read.

In order to simplify the discussion of the various outcrops, I have divided the entire region into three areas, viz.: The southern Kansas area, the Smoky-Blue area, and the Nebraska area. The first of these occurs in southwest Kansas, and contains the following four localities: Belvidere, Clark county, Cimarron-Bear, and Arkansas localities. The second area extends from the Arkansas river, at Great Bend, to the Big Blue river, near Beatrice, Neb. In the discussion it will not be subdivided. The third area, which lies for the most part in eastern Nebraska, consists of the Salt Creek, Platte, Missouri, and Big Sioux localities. This division differs essentially from that of Doctor White, who includes in his “Southern Interior” region all the formations south of the Platte river, and in the “Northern Interior” region all lying north of this stream. It is obvious that both of these divisions are purely arbitrary, and have been adopted simply as a convenient schedule of classification. My divisions, in particular, are purely local, and are nothing but convenient groupings for purposes of discussion.

The exposures of the Dakota of the first or southern Kansas area are overlaid by the Tertiary, and grade conformably upward from the Comanche. The Dakota of the second area rests conformably on the Comanche, or unconformably on the Permian, and is capped with the Benton, except in southern Nebraska, where

Glacial deposits have protruded. The rocks of the third area rest on the Permian and Carboniferous and are covered by the Benton and glacial.

The limit of glacial deposits cuts the strike of the Dakota nearly at right angles not far from the Kansas-Nebraska state line. The line of boulders indicating the position of the terminal moraine enters Kansas near Kansas City and follows roughly the course of the Kansas, Blue, and Little Blue rivers, usually extending a few miles south of these streams. The northeastern corner of Washington county, Kansas, is covered with the characteristic drift boulders, and in places by the loess. Southwestern Jefferson county, Nebraska, just across the state line, is beyond the line of drift. The largest exposed area of Dakota in Nebraska is in this locality. In all other parts of this state exposures occur only along bluffs, or as isolated points where post-glacial erosion has removed the later deposits. It has been estimated that, although the Dakota in Nebraska originally covered what would constitute more than twenty counties, the total amount of visible exposures, if grouped together, would not comprise a single county the size of Lancaster or Gage.

SOUTHERN KANSAS AREA.

Belvidere Locality.—This locality is chiefly known as being the type locality of the Comanche series of southern Kansas. Some of the geologists who have visited this region are Cragin, Hill, Prosser, Ward, and Stanton. All of these gentlemen have noticed the presence of Dakota-like boulders and ledges on many of the hills in the vicinity. To this rock Professor Cragin gave the name "Reeder sandstone." In 1897 Dr. Lester F. Ward and the writer first worked out the relations of the Comanche to the superjacent beds.

The Comanche of the region consists of two distinct formations. Resting unconformably on the Red Beds is the Cheyenne sandstone, consisting of rather fine-grained, variously colored sandstone with intercalated beds of shale, often carbonaceous, and containing an abundant flora, chiefly dicotyledonous. The extreme thickness of the Cheyenne is between forty and fifty feet. Resting conformably upon the Cheyenne is the Kiowa shale, a marine deposit consisting of about 150 feet of dark blue to black papyraceous shale, with occasional layers of soft, sandy shale and of hard limestone. The fossils consist of invertebrates, including insects, numerous mollusks, and vertebrates, with reptilian forms predominating. In the paper containing the results of the investigations made in 1897,⁴³ mentioned above, the term "Medicine Beds" was applied to a series of transition beds supposed to be intermediate between the Comanche and the Dakota. (See pl. IV.)

At the time the paper was written it was not known that fossils were present in the beds. Doctor Stanton has since found shells which do not differ from those in the underlying Kiowa nearly as high as the Dakota. In view of this fact, it would, perhaps, be better to discard the term "Medicine Beds" and class all the strata in either the Comanche or the Dakota, although the exact line of demarkation can scarcely be drawn. This brief description of the Comanche of the Belvidere locality has been introduced here because of the fact that this is the basal formation of the Cretaceous of the two states. The literature of the subject is ample and will repay perusal.⁴⁴

The best exposures of Dakota in this region are on the upper Medicine river, ten miles west of Belvidere and about the same distance south of Greensburg, Kan. The rock is the typical brownish-red sandstone, containing great numbers

43. Am. Jour. Sci., 5: 169-175.

44. See Charles S. Prosser's resume, Univ. Geol. Surv. of Kans., 2: 96-111. Also "The Lower Cretaceous of Kansas," Am. Geol., 25: 12-26.

of ironstone concretions. Rather poorly preserved dicotyledonous leaves are found in a few ledges. Other exposures of the sandstone are at Blue Cut mound, two and one-half miles south of Belvidere, and on the high hill south of the forks of the Medicine river, five miles west of the same place. The sandstone is everywhere covered unconformably by the Tertiary, and doubtless extends under this covering west to Clark county and north to the Arkansas river.

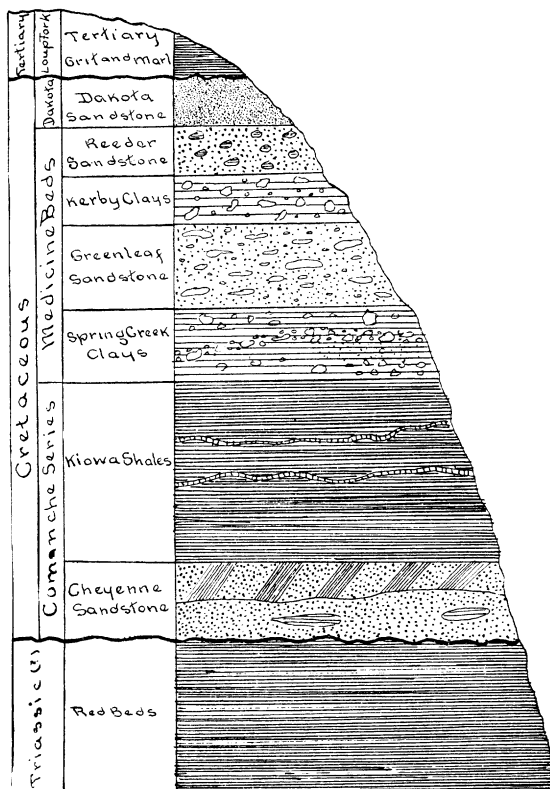


PLATE IV. Geological section at Belvidere.

Clark County Locality.—The general features of the Cretaceous of Clark county do not differ from those of Belvidere, except that here the Cheyenne is wanting. The base of the Kiowa rests unconformably on the unevenly eroded surface of the Red Beds. The fossils and stratigraphy of the Kiowa are very similar to the Belvidere locality, with the exception that in Clark county there is usually a greater proportion of arenaceous shale in the upper layers. The Kiowa grades upward through the more or less pronounced transition beds into the typical dark-brown and black Dakota sandstone. The outcrops of the Dakota occur in a line from northeast to southwest for a distance of twenty miles, from Bluff creek, ten miles north of Ashland, across the head of Hackberry, East Bear, West Bear, Chatman, Big Sand, and Kiger creeks, as far as the Little Basin, in the western part of the county. These creeks cut the line of outcrops nearly at right angles. Professor Cragin reported forty feet of dark-brown sandstone from the head of West Bear creek. At the same place Professor Prosser measured seventy feet. In 1898 Doctor Ward, Doctor Stanton and the writer

made a section on Cheyenne cañon, a tributary to upper West Bear creek, in which the distance from the Kiowa to the Tertiary was found to be 145 feet. Of this thickness, twenty-five feet was sandstone and the rest clay shales. Iron-stone concretions are abundant in all parts of the formation, and by their prevailing dark-brown color render the slopes conspicuous for long distances. In this locality leaves were found in nearly every horizon above the Kiowa, becoming more abundant in the upper layers. On the east bank of Chatman creek, not more than a mile from Cheyenne cañon, the first leaves collected in the locality were found by Doctor Ward, in 1897; and from this place the best collections of the region have been obtained, although dicotyledons have been found in greater or less abundance in every outcrop in the county.

The Cimarron-Bear Locality.—Under this head have been included a number of isolated exposures of the Dakota in the extreme southwestern part of the state. These deposits of sandstone are cut off from the other outcrops of this group by more than 100 miles of Tertiary. It is along the bluffs in the valleys of Bear creek (which must not be confused with Bear creek in Clark county) and the Cimarron river and their tributaries that the dark-brown sandstone outcrops. Point of Rocks, in Morton county, a line of bluffs on Bear creek, in Stanton county, and several exposures between these, on the North Fork of the Cimarron, are referred to this group. The line of outcrops extends beyond the limits of the state into Colorado. For the most part, the rock is soft, rather light brown in color, and contains much clay shale. It is in demand for building purposes only because it is the only rock found in the region. Leaves are reported from the bluffs of Bear creek, and persistent search can scarcely fail to be rewarded in a formation that is so uniformly fossiliferous.

The Arkansas River Locality.—Along the Arkansas river, from Dodge City to Great Bend, a line of low bluffs runs parallel to the river on the north side. These bluffs are composed of Dakota sandstone, and are capped by the Tertiary. They are, in most places, from two to five miles back from the river; in one place only does the river wash the bluff. This is three miles east of Ford City. At but two points are the bluffs in any way conspicuous: at Pawnee Rock and at Jenkins bluff, near Larned. Pawnee rock, on the old Santa Fe trail, is a bold shoulder projecting into the valley. The rock in this locality is quite hard, sometimes almost quartzitic, and is being blasted away to furnish building stone. Pawnee rock covers perhaps an acre, and the face of the cliff is some thirty feet high. From its top a narrow ridge runs back half a mile or more to the main line of bluffs. This spot is famous for the tales of terror connected with Indian massacres.

Near Larned, on the north side of the Pawnee river, the sandstone forms a number of prominent bluffs. The most conspicuous is Jenkins bluff, three miles west of the city, near the site of old Fort Larned. This hill is about 150 feet high, and exhibits the usual sequence of shales and sandstones. Fossil leaves are found both at this place and at Larned. The sandstone bluffs extend for a number of miles up Pawnee river and Walnut creek, both of which enter the Arkansas from the north. Toward Great Bend the line of bluffs recedes from the river, and the sandstone finally disappears beneath the Upper Cretaceous deposits on the divide between the Arkansas and the Smoky Hill.

SMOKY-BLUE AREA.

Under this head will be included all the region that drains into the Kansas river. The line of outcrops here, as in other localities, runs northeast and southwest. Six principal tributaries of the Kansas, flowing southeast, cut this line

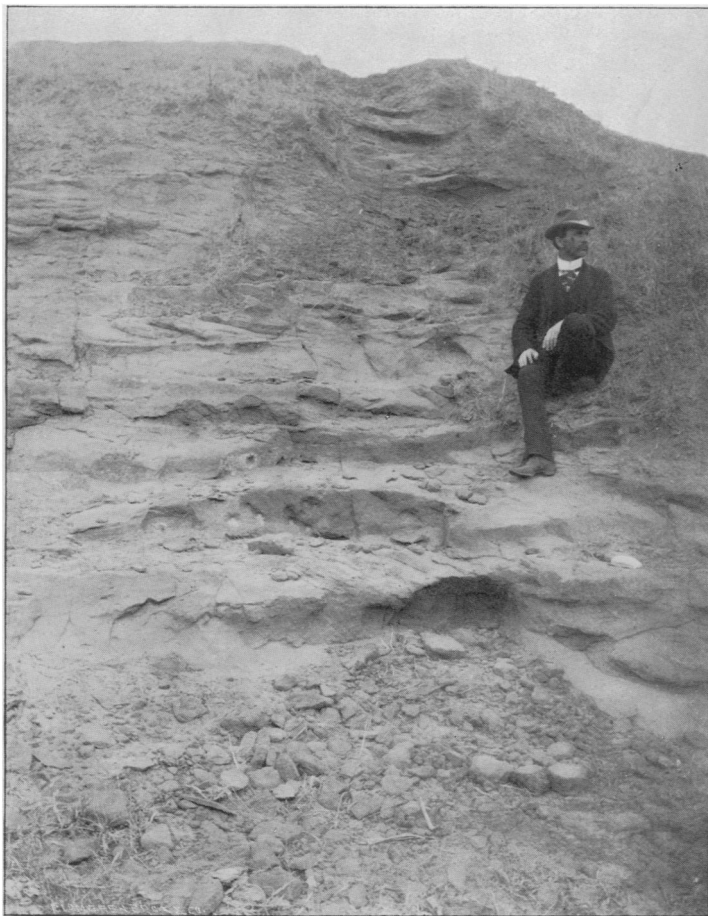
approximately at right angles. Beginning on the south these streams are: Smoky Hill, Saline, Solomon, Republican, Little Blue, and Big Blue. Where they break through the line of hills all of these streams have cut rather narrow valleys in the sandstones and shales. In this regard they are in marked contrast to such streams of the plains as the Arkansas, Ninnescah, Platte, or Loup, which have broad and shallow valleys. This area constitutes the most typical section of the Dakota group. It is here alone that the entire thickness of strata from the underlying Permian to the superjacent Benton may be seen throughout any considerable area. The topography also differs materially from that of other regions. It is characterized by bold cliffs, flat-topped buttes and mesas, square shoulders and ledges, interspersed with steep slopes and here and there narrow cañons. This angularity of topography contrasts strangely with the gentle, rounded slopes of the Benton or Permian. The conditions indicated obtain for the greater part of the area. South of the Smoky Hill river the Dakota is covered by the Benton or by the Tertiary; and the asperity of bluff and butte is much subdued. The same is true of the country between the Little Blue and Big Blue rivers, where glacial deposits have protruded. In this locality the outcrops are confined to bluffs near the streams where erosion has removed the later deposits.

The area under consideration is about 100 hundred miles long, with an average width of perhaps thirty miles. The greatest width is not far from sixty miles, extending from the high hills in western Marion county, where the base of the Dakota first appears, along the Smoky Hill river to a point in southern Russell county, where the last trace of the Dakota disappears under the Benton. This extreme width is due to two causes: the outlier of the Dakota, which in Marion county extends far east of the main body, and the long tongue of sandstone, which follows for a great distance up the valley of the Smoky Hill. Similar tongues follow the valleys of all the streams mentioned above. On the other hand, the shortest distance from the Permian is less than ten miles, as at Brookville, Kan., or on the state line, as mentioned above. The outcrops of the Dakota in this area occupy portions of the following counties: Barton, Rice, McPherson, Marion, Ellsworth, Saline, Lincoln, Ottawa, Mitchell, Cloud, Clay, Republic, and Washington, Kansas, and Jefferson and Gage, Nebraska.

NEBRASKA AREA.

Salt Creek Locality.—All the exposures of this locality are in Lancaster county, Nebraska, except a few that are just across the Seward county line near Pleasantdale. In nearly every instance these exposures occur on the bluffs along the valleys of Salt creek and its tributaries. They are usually quite restricted in area, often occupying but a few hundred square yards. The greater part of the outcrops occur within a few miles of Lincoln, although outliers are found at a distance of from ten to twenty miles in every direction. Near Roca and Bennett, in the southeastern part of the county, the Dakota is found within a few feet of the Permian; although in no instance has actual contact been observed. The most eastern exposure is at Bennett, where there is a thirty-foot vertical cliff of the Dakota capped by ten feet of Drift boulders. (See plate V.) The Carboniferous (or Permian) limestone is exposed both north and south of the Dakota on a level several feet higher than the top of the sandstone. This furnishes a good example of the conditions so often observed throughout the Dakota area, where the sandstone has been deposited in eroded hollows of the old Carboniferous floor.

Wells in the vicinity of Lincoln reach the Carboniferous limestone at a depth of 270 feet. The Benton limestone near Milford is about 100 feet above the alti-



Ledge of Dakota sandstone, hill south of the penitentiary, Lincoln, Neb.
Photo by Jeffords.

tude of Lincoln. This would indicate that the thickness of the Dakota in this locality is between 350 and 400 feet, which agrees well with the thickness in other localities. A recent publication by Mr. N. H. Darton, of the United States Geological Survey, gives a much more comprehensive report of the Lancaster county outcrops.⁴⁵

The Platte Locality.—This is the only locality in the Nebraska area where the nonconformity between the Carboniferous and the Dakota may be seen. The outcrops occur on both sides of the Platte river, from Plattsmouth to Fremont, a distance of fifty miles. The fact of the extreme irregularity of pre-Cretaceous erosion is here well exemplified. One of many examples may be cited on the north side of the river, nearly opposite Louisville, where two instances of nonconformity, not more than a quarter of a mile apart, differ eighty feet in altitude.

The numerous limestone quarries along the river usually exhibit more or less of the Dakota between the Carboniferous below and the glacial above. In this case there are of course two nonconformities: the first between the Carboniferous and Dakota, and the second between the Dakota and the drift. Often the lines of the two non-conformities are but a foot or two apart, indicating that during preglacial time the sandstone was almost entirely removed by erosion. In other places the Dakota has all disappeared and the drift rests directly upon the unevenly eroded Carboniferous limestone. Again, the sandstone forms high cliffs, as at the Santee caves, opposite Ashland. The most westerly exposure known in the locality is a small outcrop in the bluff where the west road leaves the river, two miles south of Fremont.

The Missouri Locality.—From Omaha to Ponca is 120 miles. Between these two places, along the bluffs on the west bank of the Missouri river, the Dakota is exposed almost constantly. In places the mantle of loess covers the sandstone to the depth of several feet, and the latter may not be exposed for miles. Usually, however, the more or less conspicuous outcrops may be seen half way up the slope. Not infrequently the presence of springs issuing from the loess indicate that the water-bearing Dakota lies just beneath the surface.

In the northern part of the locality, near Homer, Jackson, and Ponca, the upper part of the bluffs are composed of Benton limestone. At the High banks, a mile north of Decatur, at Blackbird hill, and at the old mission, the Missouri washes cliffs of Dakota sandstone. It was these bluffs standing boldly out into the river that caught the attention of the early explorers. Much historical interest attaches to these places. This is not only the type locality of the Dakota, but is also the region concerning which the early controversy waged, and the place where the question was finally settled.

Big Sioux Locality.—Under this head are included the exposures east of the Missouri river, near Sioux City, Iowa. At Riverside park, on the east bank of the Big Sioux river, a mile from its mouth and three miles from Sioux City, the following section was taken illustrating the position of the beds:

No. 6. Loess	10-100 feet.
No. 5. Drift	5 "
No. 4. Thin limestones and shales, Benton	5- 10 "
No. 3. Yellow, blue and gray shales and clays, containing shells and concretions.	60 "
No. 2. Heavy ledge of sandstone containing leaves	15 "
No. 1. Slope from Big Sioux river	20 "

No. 2 is quarried for building stone and from No. 3 clay is obtained for several brick and tile works. The exposures of both Dakota and Benton are said to

45. Water Sup. and Irriga. Papers, U. S. Geol. Surv., No. 12, pp. 16-19.

extend for a number of miles up the Big Sioux river. At Sioux City an exposure may be seen at Prospect hill, a bold bluff on the bank of the Missouri.

From this place the river crosses the broad valley and strikes the bluffs on the west side at the old mission, some twenty miles below. On the east side the bluffs trend to the southeast. A shoulder standing boldly out toward the river has received the name Sergeant's bluff, in honor of Sergeant Floyd, a member of Lewis and Clarke's party, who was buried on its summit. It is on the face of this bluff that the Dakota clay, which is very similar to that at Sioux City, is being excavated for brick and tile. The exposure is a quarter of a mile long, and the total thickness of the beds is said to exceed fifty feet. A considerable portion, however, consists of sandstone arranged in lenses and pockets; and near the top is a rather heavy sandstone ledge. Numerous leaves are found in some reddish-brown concretions scattered throughout the shales.

For maps showing the exposures of the Dakota in Kansas and Nebraska, reference is made to the University Geological Survey of Kansas, vol. II, pl. XLVII, for the Kansas areas, and to the Nineteenth Annual Report of the United



PLATE VI.

States Geological Survey, part IV, pl. LXXXII, for those of Nebraska. The first map is by Haworth and the second by Darton. The foregoing reduced map of the two states is intended to show graphically the exposures throughout the entire region discussed in this article. The stippled portions indicate Dakota areas.

STRATIGRAPHY.

LINE OF UNCONFORMITY.

The line between the Paleozoic and the Mesozoic rocks in Kansas and Nebraska is one of unconformity. The Triassic and Jurassic rocks are totally wanting, unless they are represented in the upper part of the Red-beds of Kansas and Oklahoma.⁴⁶ The Carboniferous rocks in the eastern part of the two states grade upward through the Permian to the point of unconformity. From this line the Cretaceous formations succeed each other in regular sequence to the western limits of the states, and far beyond. The rocks of both great eras, Paleozoic and Mesozoic, thicken to the south. On the Oklahoma line there are some 2200 feet of strata between the upper part of the Carboniferous and the base of the Cretaceous. At the Kansas-Nebraska line there are not to exceed 200 feet, while at the mouth of the Platte river the Dakota rests directly upon the upper surface of the eroded Carboniferous. In the Belvidere region the Cretaceous rocks below the base of the Dakota measure 250 feet, in central Kansas they are not more than 100 feet thick, while at the Nebraska line the Dakota rests directly upon the Permian.

In other words, there are on the Oklahoma line about 2500 feet of strata between the top of the Carboniferous proper and the base of the Dakota, while on the Platte river these beds have been entirely eroded away and their place is represented by a hiatus; the sandstones of the Dakota resting upon and filling up the hollows of the old Carboniferous floor. This fact was commented upon by Doctor Hayden, who, although he had not all the facts at command, yet lays especial emphasis on the uneven erosion of the Carboniferous during Triassic and Jurassic time. Beyond the limits of the territory discussed in this article the amount of pre-Cretaceous erosion is still more strongly marked. In Iowa the brown, leaf-bearing sandstone rests unconformably upon the middle, or perhaps the Lower Carboniferous, and in Minnesota the Dakota is found in the hollows of the Trenton or even of the Cambrian.

The superjacent strata are also quite varied. In the southern part of the area the Dakota is covered with the Tertiary. In McPherson county, Kansas, the Equus beds cap the group south of the Smoky Hill river. From near the state line throughout the entire state of Nebraska, all the older formations are covered with a mantle of glacial deposits. All of these rest unconformably upon the Dakota. From the Arkansas river to Iowa the Dakota is everywhere superseded conformably by the Benton and this by the Niobrara.

Plate VII shows the relative position of the various formations contiguous to the Dakota in Kansas and Nebraska. Continuous lines represent unconformity.

BASE OF THE DAKOTA.

A question which might prove a vexing one, did we permit ourselves to consider it such, is that of the line of separation of the Dakota from the sub- and superjacent Cretaceous groups. At first glance it would seem necessary that a

46. Since the above was written, it has been demonstrated that the upper part of the problematic Kansas-Oklahoma Red-beds is Triassic. Vertebrates taken from the lower part of these beds, in eastern Oklahoma, have been identified by Dr. S. W. Williston as Permian forms, similar to those from the Texas Permian. On the other hand, invertebrates obtained from near the top of the Red-beds in western Oklahoma are classed as Triassic forms, on the authority of Dr. J. W. Beede and Mr. Charles Schuchert. The line of separation between the two series of rocks has been drawn provisionally at the heavy ledge of gypsum that caps the Gypsum Hills of Kansas and Oklahoma. See First Biennial Report of the Oklahoma Geological Survey.

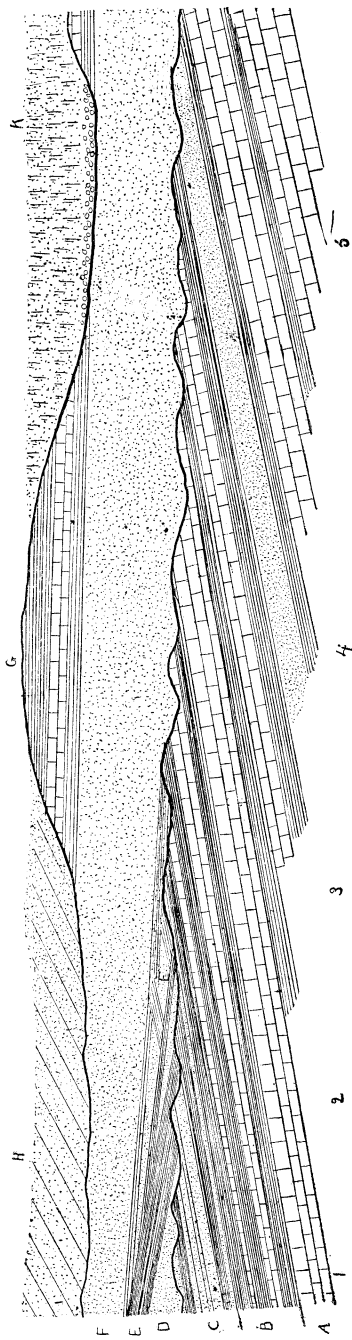


PLATE VII.—Geological section, showing unconformities below and above the Cretaceous along the line of Dakota outcrop in Kansas and Nebraska.

Formations.		Conditions and Unconformities.		Formations.	
A = Carboniferous.		1. At Belvidere — Cheyenne unconformable on the Red Beds.		E' = Mentor.	
B = Permian.		2. In Clark county — Kiowa unconformable on the Red Beds.		F = Dakota.	
C = Red Beds.		3. In Saline county — Mentor unconformable on the Permian.		G = Benton.	
D = Cheyenne.		4. At State line — Dakota unconformable on the Permian.		H = Tertiary.	
E = Kiowa.		5. On Platte river — Dakota unconformable on the Carboniferous.		K = Glacial.	

fixed line be drawn in order sharply to define the limits of the various formations. This, however, it seems difficult to do.

It should be remembered that Doctor Hayden, who named and described the group, did not at that time know of the existence of older Cretaceous rocks in the west; but supposed that the Dakota was the basal member of the Cretaceous and rested in all places directly upon the Carboniferous or Permian. It is the presence of Lower Cretaceous formations immediately beneath the Dakota that seemingly complicates the problem. In regard to the upper limits of the group, Doctor Hayden frankly admits that there is great difficulty in drawing the line between the Dakota and the Benton, because of the fact that both the stratigraphy and fossils of the two groups blend in numerous localities. In speaking of the exposures near Sioux City, he says: "Lithologically, it is impossible to draw the line between these formations here. No. 1 (Dakota) passes so imperceptibly into No. 2 (Benton), and No. 2 into 3 (Niobrara), that there is no break, and yet their principal characteristics are very distinct. The first is a sandstone, the second a black, plastic clay, and the third a chalky limestone; and yet I cannot tell the exact point where one commences and the other ends."

If this be true for the line between the Dakota and the Benton, what shall be said of the base of the Dakota, where conditions are much more complicated? As far as the observations of the writer go, it is rarely difficult, in any one of the dozens of localities he has visited in Kansas, Nebraska, and Iowa, to decide upon a line of separation, at least approximately, between the Dakota and the Benton. The sandstones of the former group gradually thin out, yellowish arenaceous shales become prominent, these become darker and more argillaceous, and are succeeded, at a distance of from fifty to eighty feet above the last sandstone, by the typical *Inoceramus* limestone so characteristic of the Benton.

The conditions at the point of separation of the Comanche and Dakota are quite different. In the localities where the best exposures of rocks of both these series occur, Belvidere, and Clark county, Kansas, the upper member of the Comanche, known as the Kiowa shale, consists of about 150 feet of dark, papyraceous shale, usually becoming arenaceous above. This shale contains a characteristic marine fauna, both vertebrate and invertebrate, which is frequently less abundant in the upper layers. Before the fossils disappear, the shales are, in places, superseded by ledges of sandstone more or less massive, and as much as fifty feet thick. In other places no fossils are found above the shales. The sandstone ledges become more pronounced and soon begin to contain a dicotyledonous flora.

In central Kansas similar conditions obtain. As has been stated, in this region the rocks which occupy the lower part of the Cretaceous groups were first classed as Triassic, then Jurassic, then Dakota, then called "Mentor beds"; and are now recognized as representing the northern limit of the Comanche or Belviderean sea. Paleontologically, these measures differ but little from the Kiowa of southern Kansas. Stratigraphically, the rock is very like the Dakota, or, rather, it combines the characters of the Kiowa and Dakota. In a section taken near Marquette, Kan., which is probably typical as regards stratigraphy, there are twenty-nine feet of sandstone and seventy-six feet of shale.⁴⁷ The shale predominates in the lower part of the section, where it is very like the Kiowa. Above, sandstones occupy the greater part of the thickness. The upper stratum in the section is a heavy ledge of rather hard, dark-brown sandstone, which contains an abundant Mentor fauna, of which Doctor Stanton has recognized twenty-two forms. Fifty feet below this ledge is a layer of soft sandstone

47. American Geologist, 25:35.

containing Dakota leaves. From this ledge the following species have been recognized: *Sterculia* sp., *Eucalyptus dakotensis* Lx., *Myrica longa* Lx., *Salix proteafolia* Lx., *Sequoia* sp., *Sassafras cretaceum* Newb., *Sassafras mudgei* Lx.

It is the fact of the overlapping of the Dakota leaves and the Comanche shells that seemingly complicates the problem of the line of separation, which, from the standpoint of stratigraphy alone, is sufficiently vexing.

Professor Mudge states that he found shells and leaves in the same ledge. This condition has not been noticed by the writer, but there is no reason to doubt the correctness of the statement. The Kiowa and its synonym, the Mentor, are evidently deep-sea deposits. At the close of Comanche time, and especially in the northern part of the area, the sea bottom was probably raised nearly out of the water. Many islands appeared. Numerous inlets, bays, bayous and lagoons were formed. Neither was the elevation constant. Depressions occurred, and marine shells flourished in the deeper bays. South of Mentor, Saline county, there is a ledge of oyster shells two feet thick. In the brackish- and fresh-water lagoons and inlets such forms as *Unio* predominate. A locality five miles north of Salina yields only fresh- and brackish-water forms. The islands were covered with dicotyledonous trees. The leaves blown off by the wind or falling in the course of nature were washed about by the tides and currents, sometimes being deposited near the shore, and again being carried into deep water. As the land was raised more and more the marine shells gradually perished, and only brackish-water forms remained. These are occasionally found throughout the entire group. In the upper part of the formation, after something like 300 feet of strata had been deposited, the increasing number of invertebrates, as well as such lithological phenomena as saliferous shales and lignites, herald the subsidence of the surface preparatory to Benton sedimentation. This group contains a marine fauna quite distinct from that of the Comanche.

As was remarked above, in the southern Kansas areas the question is considerably simplified. The Kiowa grades upward through a series of beds more or less transitional in character into the true leaf-bearing Dakota. As far as known, the thickness of the strata, from the upper layer yielding invertebrates to the lowest sandstone containing leaves, is nearly 100 feet. Doctor Ward rightly considers these transition beds the true base of the Dakota group. This would be equally true of the central Kansas region. The fact of the overlapping of the fossils may be considered accidental, or rather incidental, depending on the peculiar conditions surrounding the deposition of the material.

In view of these facts, it does not seem either necessary, expedient, or possible, in the present state of our knowledge, to fix an arbitrary line of separation between the Comanche and the Dakota. The conditions, as outlined above, are such that such an attempt at a fixed demarkation limit is at least impracticable. Taking Meek and Hayden's classic section as a criterion, the base of the Dakota would probably be placed at the lowest sandstone ledge. The invertebrate paleontologist might be tempted to squeeze the Dakota into the narrow limits between the shell-bearing horizons, the one at the base and the other in the upper part of the group; and, on the discovery of shell beds throughout the formation, to draw a line near the middle of the group, and, calling all below this line Comanche and all above Benton, to eliminate the Dakota entirely. The vertebrate paleontologist would probably draw the upper limit of the Comanche at the highest stratum yielding vertebrate remains. The phytopaleontologist may perhaps be pardoned for insisting that the lines of demarkation of a group characterized almost exclusively by plant fossils be determined by the same criteria.

GENERAL CHARACTER OF STRATIGRAPHY.

To the cursory observer traveling through central Kansas or along the "Bench road" from Tekamah to Decatur, Neb., it might appear that sandstone ledges occupied the greater part of the Dakota group. The most conspicuous objects are bold and rugged shoulders, buttresses, and cliffs of massive sandstone. This sandstone is of all shades of color, from gray to black, with brownish red predominating. The ledges may, in fact, be traced for miles, forming the escarpment of a ridge or outcropping as a definite ledge along the side of a bluff. Such geologists as Hayden and Capellini seemingly failed to recognize the fact, or at least did not record it, that the greater part of the Dakota group is not sandstone, but consists of sandstones and shales. At a conservative estimate, at least two-thirds of the rock of the group is not sandstone. It is true that in many places they are strongly arenaceous, but not enough so to constitute them sandstones.

The shales and clays of the Dakota vary much both in texture and color. Not infrequently they are black and papyraceous, reminding one very much of the Kiowa. Usually, however, they are white, blue, or yellow, with many bands of red or green. A Dakota clay bank ordinarily presents a variety of colors. The darker shales are usually more highly argillaceous; while the lighter colors, such as yellow and gray, indicate a greater amount of sand. Another fact that should not be allowed to escape notice in a systematic study of the group is the non-continuity of both sandstones and shales. There are almost no persistent ledges of hard rock with shales between, as is the case in either the Permian or Benton. For example, the Cottonwood limestone, near the top of the Carboniferous, is persistent for over 200 miles; and in the Benton the "fence-post limestone" may be traced perhaps half as far. Nothing like this occurs in the Dakota. It is true that in a few instances pronounced ledges may be traced across one or two counties. As examples may be cited the ledge along the Missouri river below Sioux City; also the ledge which caps the Smoky Hill buttes and Soldier Cap mound, in Saline county, Kansas, and forms the escarpment along Spring creek, above Brookville, as far as the Ellsworth county line. (See plate VIII.) Even these ledges, however, which are exceptions to the general rule, vary much in thickness.

Throughout the group the sandstone is not constant in lithological qualities. It represents all degrees of hardness, from very soft sand, which may be crushed with the fingers, to the hard, brittle, clay-ironstone concretions, which turn the edge of the hardest steel. A bank of argillaceous shale will oftentimes become arenaceous, change to soft sandstone, and this, in turn, become hard enough to form conspicuous ledges; all in less than 100 yards. Not infrequently these changes may be observed several times in the course of a few miles, the ledges appearing and disappearing with no apparent regularity.

Massive and conspicuous ledges are not uncommon. Doctor Hayden assigns to the ledge above Blackbird mission the thickness of from sixty to eighty feet. At Tekamah, Neb., it is over fifty feet from the bed of Tekamah creek to the top of the railroad cut; and the entire thickness is through the coarse, dark brown sandstone. At the Santee caves, on the Platte, a sixty-five foot ledge is exposed. On Mulberry creek, in eastern Ellsworth county, Kansas, a mile east of the famous cave section, a ledge measures seventy feet; and at the mouth of Alum creek, ten miles south, is one nearly as thick. These, however, are exceptions. Ten feet would, perhaps, be a fair average for the thickness of Dakota ledges.

The strata of clays and shales are usually much thicker; but because of the fact that they are composed of softer material are more easily denuded. A

covered grassy slope is ordinarily indicative of a shale bed; and it is but necessary to notice how large a per cent. of the Dakota area is occupied by these covered slopes, in order to get a tolerably correct idea of the amount of shaly material contained in the group. It is because of the fact that the shale is covered that it has so persistently escaped notice. It should, perhaps, also be noticed in this connection that in many, perhaps most, cases these covered slopes are strewn with boulders and fragments of rock from the ledges above. These often give the slope the appearance of a rocky ledge, when the underlying strata consist of shale and clay.

Mr. Logan distinguishes two general groups in the Dakota: a lower or ferruginous group, and an upper or saliferous group. The upper group is divided into a lignite horizon, a salt-marsh horizon, and a gypsiferous horizon.⁴⁸ It is not the understanding of the writer that Mr. Logan intended these as general divisions of the entire group, but rather for that part which he studied, viz., the area between the Smoky Hill and the Republican rivers. The conditions noted by Mr. Logan obtain for the region described by him, but are not characteristic of the entire group. Saliferous shales and lignites seem to be found rather more abundantly in the upper than in the lower beds; but even this statement must be considered general rather than specific. After four years spent in studying the various horizons, from Oklahoma to Minnesota, the writer is reluctantly forced to the conclusion that any persistent or general division of the Dakota group is not only impracticable, but, in the light of our present knowledge, impossible. That he would prefer it otherwise will be apparent from the discussion of the flora of the group. In this connection a quotation from Doctor Lesqueux seems pertinent:

" . . . The whole group bears, with scarcely any change in the nature and compound of its strata, the same essential character, from the lowest strata to the line of conjunction with the Fort Benton above it. . . . The compound is essentially the same in the whole thickness and in the whole extent, varying only in the degree of hardness, compactness, and red coloring resulting from the different proportions of oxide of iron with which it is impregnated."⁴⁹

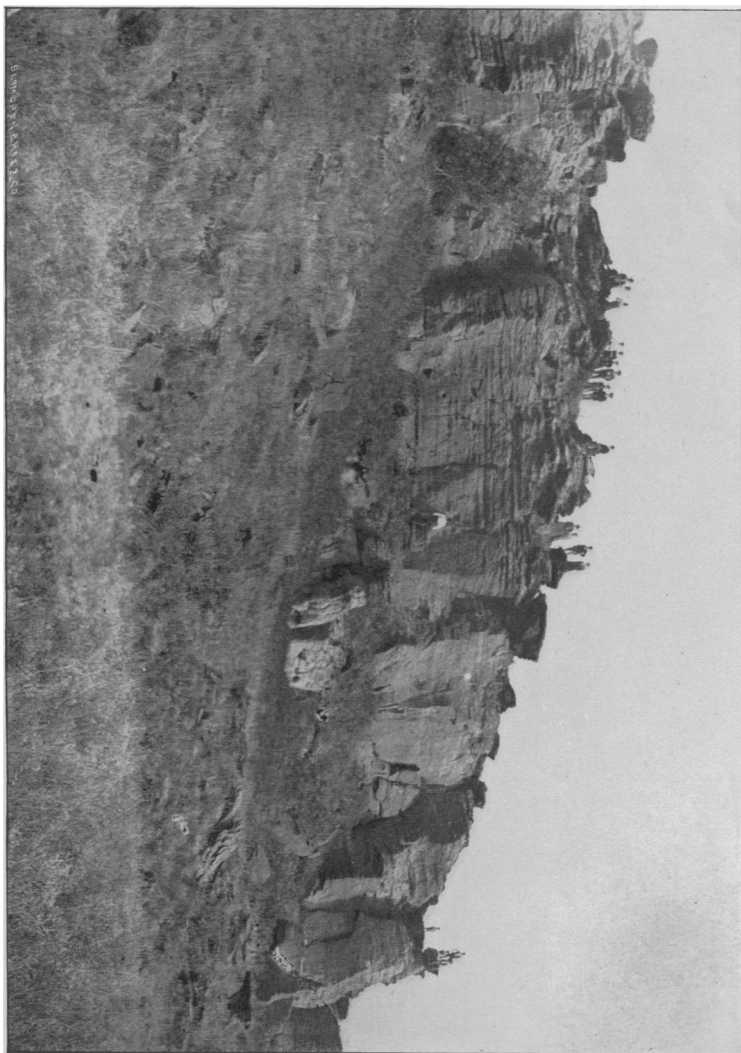
ORIGIN OF DEPOSITS.

There has been no little diversity of opinion regarding the origin of the material, and especially the conditions incident to the deposition of the Dakota group. Professors Capellini and Marcou considered the formation a fresh-water deposit. This was due to the small proportion of calcium contained in the rock, as well as the general paucity of marine fossils. Meek and Hayden, who had better opportunities for observation, considered the beds marine; and in proof of their position cited the presence of a few marine invertebrates in the upper beds at Sioux City.

The fossils found in Kansas in what are now known to be Lower Cretaceous horizons were also taken as evidence that the beds were of marine origin. Doctor White, on the contrary, was disposed to consider the group in general as non-marine. There are grave difficulties in either position. The extent of the group and the homogeneity of its constituent parts would seem to vitiate the theory of fresh-water origin. It is very unlikely that a fresh-water deposit would cover an area the size of the Dakota. On the other hand, the dicotyledonous flora, the absence of limestone and the extreme scarcity of marine shells throughout the greater part of the group preclude the idea of deep-sea deposits. Both of these views being untenable, another must be sought.

48. Univ. Geol. Surv. of Kansas, 2: 207-209.

49. Cretaceous Flora, p. 23.



Roaring Spring cliff, north of Terra Cotta, Ellsworth county, Kansas, showing Dakota sandstone. Photo by Jones.



Pulpit rock, Alum creek, Ellsworth county, Kansas.
Photo by Beede, 1900.



Mushroom rock, Alum creek, south of Carneiro, Ellsworth county, Kansas.
Photo by Beede, 1900.



Table rock, in southeast Lincoln county, now destroyed.
Photo by Jones, 1899.

Doctor Lesquereux, nearly thirty years ago, promulgated a theory to account for these beds, which to the mind of the writer is the most reasonable of any yet advanced. It will be given in a somewhat abbreviated form in the language of the noted author. After pointing out the resemblance of the Dakota to certain sandstones of Devonian and Carboniferous ages, Doctor Lesquereux says:

"The origin of these groups of sandstone is the same, to my belief at least. They are beach formations, like those in progress at the present time along the shores of the North Sea, in Holland and Belgium, where the widely extended, muddy shores are formed of a soft substance of the same red color. As I have had opportunity to examine it, it is a mixture of small grains of sand, brought from the sea with the mud deposits, carried by rivers of long course, after traversing flat countries. By slow deposition it constitutes low shores, successively washed by the tides, which of course recede or advance farther in proportion to the slow upheaval or depression of the land. Marine animals, the shells especially, are very rare in a formation of this kind."⁵⁰

Then follows a short discussion of the leaves of the Dakota, from which the conclusion is drawn that the essential types of the vegetation are those of low islands and shores, rather than of hills and dry land. In speaking of the origin of the leaves, he remarks:

". . . The Cretaceous leaves have been derived from trees or groups of trees growing in the vicinity of muddy bottoms, where they have been buried and fossilized. . . . The deposits seem to have been local, dependent upon circumstances. There must have been, necessarily, an arm of the sea, with soft, sandy mud, bordered by the adjoining dry land covered with a forest. The characteristics of the local deposits indicate that the forests were on small islands scattered over the Cretaceous sea."

". . . The formation of the Dakota group is the result of muddy flats whose surface, raised perhaps in hillocks above water limits, and already solid ground, was cut like an immense swamp, here and there interspersed by rare groups of trees and bushes. Of course the main portion of this surface was subject to continuous change in the successive modifications resulting from the heaping and displacement of matter by water, and thus the leaves were distributed either at the same place but at different levels, or at the same level but at different localities."

To this it seems necessary to add that recent investigations in the field but confirm the accuracy of the theory.

PECULIAR FORMS OF STRATIGRAPHY.

While the ordinary characters of Dakota stratigraphy are those described, yet throughout the group there are departures from the normal form that deserve especial notice. These peculiar forms may be confined to special localities, or, as in the case of nodular concretions, may be distributed throughout the entire group. These concretions vary greatly in form, size, and color. Oftentimes they are small and box-shaped, with angular corners and edges, an inch or two across, with a predominating dark-brown color. They break with a conchoidal fracture, exposing cutting edges. The enclosed cavity is usually filled with white or cream-colored clay. More frequently, perhaps, the concretions are spherical or geodic in structure, and when broken form hollow, bowl-shaped vessels. Not infrequently these lie scattered over the surface, forming reservoirs in which rain-water collects. Very often the concretions are solid, varying in size from that of a pea to that of a baseball. These may be found either solitary or cemented into clusters. Sometimes these clusters will be grouped together, resembling a bunch of grapes; or perhaps but two will be joined, something after the manner of a double walnut.

50. Cretaceous Flora, p. 27, *et seq.*

In many places in the heavier ledges the concretionary structures assume gigantic proportions. They are often twisted and crumpled into grotesque and fantastic shapes. These forms are so radically different from anything else in the region that to the common mind they suggest volcanic action, and the geologist is often wearied with explaining to the farmers along the line of outcrops that neither volcanoes nor earthquakes had anything to do with these peculiar forms. Some of these concretions are as much as ten feet in diameter, and consist of a series of dome-shaped layers from one to two inches thick, arranged one within the other. These layers are often in direct contact; or again they may be separated by several inches. Not infrequently the inner layers have disappeared by concentric decomposition, and only the outer shell remains, often forming a cave in which a man may stand upright.

These masses of clay ironstone are often found in the form of streaks or bands throughout the sandstone, usually following the line of stratification. The box-shaped and spherical concretions described above are ordinarily found in the clay banks, but sometimes occur in the sandstone. Doctor Hayden evidently referred to these concretionary bands when he said: "There are also some seams of iron ore, which, when broken with a hammer, gave forth a sound much like that from old pot metal. It is really a pretty fair iron ore, but quite silicious and impure."

The theory of the origin of concretionary structure seems at the present time to be rather indefinite. This article makes no attempt at an explanation of these most interesting phenomena. It is a question that calls for persistent and systematic research; and it is to be hoped that some competent investigator may shortly give it his attention. When this shall be done the Dakota group will supply an abundance of material.

Throughout the Dakota area there are numerous peculiar forms of erosion. Castles, chimneys, towers and forts are some of the popular names with which these marked forms are designated. Pulpit rocks, near Carneiro, and Rock City, southwest of Minneapolis, Kan., are perhaps, the most striking forms. The pulpit rocks are on Alum creek, a mile south of Carneiro, Ellsworth county, Kansas. At this place a ledge of rather hard gray sandstone rests on a much softer ledge. Along the side of the hill the softer ledge naturally weathers away more rapidly. The upper and harder layer is in most places entirely removed, but in a few cases it persists in the form of large, irregular, spheroid masses, bearing not a little resemblance in shape to the large puffball of the prairies. Some of these rock masses are twenty feet in diameter and fifteen feet high. They are usually found lying flat on the ground, but are sometimes tilted or even on edge. In a few cases there is left a pedestal of the underlying soft sandstone, supporting a mass of rock many times its own size. In such case the similarity to a puffball is still more strongly marked. One might almost imagine that the fungus, stalk and all, had simply increased in size until it had reached its present gigantic proportions, and had then been petrified. The largest of these pulpit rocks has a pedestal twelve feet high and not more than six feet across at the top, on which is supported a globular mass of sandstone fifteen feet high and twenty feet in diameter. (See plates IX, X.) The marked stratification of the upper layer gives to the rounded mass a peculiar appearance, not unlike that of jelly-cake. This harder ledge may be seen outcropping on a number of hills in the vicinity; but in no other locality are the marked forms of erosion so conspicuous as at the spot just described.

Rock City, five miles from Minneapolis, Kan., consists of several hundred rock masses very like those at Carneiro, except that here the pedestals are

wanting and the balls rest directly upon the ground. They cover a space of perhaps two acres; and when seen from a distance present the appearance of a military encampment, or even of a city, whence the name. The masses are ordinarily globular, from fifteen to twenty feet in diameter, and have the general appearance of an Eskimo hut. They are often so close together that a person may step from one to the other. In some places are passageways wide enough for a wagon to pass through. All stages of formation and erosion may be seen, from the stage where the top of a boulder is just protruding from a bank, through forms that are only half uncovered, and complete globes, to those that have fallen to pieces and are weathering away. Table rock, in Lincoln county, Kansas, until recently exhibited the same peculiarities of form that are seen in Pulpit rock to-day, but has now fallen down. (See plate XI.) These are all pronounced erosion forms; and as such are of more than usual interest both to the geologist and to the ordinary observer.

In lithological character the hard ledges mentioned above approach a quartzite. There are several such ledges in the Dakota. In eastern Saline and northern McPherson counties, Kansas, quartzite boulders are not infrequent. Doctor Hayden refers to numerous layers from one to four feet thick, of a very compact, massive quartzite, at the Blackbird mission, Nebraska. Doctor Barbour and the writer, in October, 1890, visited a ledge of extremely hard and massive quartzite-like rock five miles northwest of Fairbury, Jefferson county, Nebraska. This ledge is gray in color, and consists of very fine grains of sand cemented with calcium. These ledges all produce an excellent building stone, and will be discussed more in detail under "Economic Phase."

One of the most peculiar forms of Dakota stratigraphy is found in the gravel-beds on the Platte river, at Cedar Creek and Springfield, Neb. At this point the Dakota rests on the unevenly eroded surface of the Carboniferous. The line of contact between the two groups sometimes differs as much as seventy-five feet in elevation in a few hundred yards. In those long-gone Mesozoic times the hills were evidently as high and the hollows as deep as those of the present time. It is in one of the lowest of these hollows that the gravel-bed has been deposited. The best exposure is a mile west of Cedar Creek, at which place the railroad has run a spur along the base of the hill for the purpose of obtaining gravel. The lower twenty feet of the Dakota consists of an extremely hard conglomerate, arranged in layers, which are usually cross-bedded and interspersed between ledges of typical brown sandstone. The conglomerate is composed of hard, water-worn pebbles of quartz, feldspar, granite, etc., varying in size from fine sand to the size of a walnut. These pebbles are cemented together by silicon into a rock which is so hard as to be broken with great difficulty. The form and color is so peculiar as to obtain for it the characteristic name "peanut rock." Above the hard conglomerate at the base of the group is found from twenty to forty feet of loose gravel and sand. It differs from the lower ledge chiefly in the size of the pebbles and the relatively smaller amount of cementing material. The pebbles are rarely larger than pigeons' eggs, and are so loosely cemented together that the material may often be removed with a scraper. The bank shows all gradations from coarse gravel to very fine sand, and is in most places more or less cross-bedded. There are some ledges of typical Dakota sandstone and a few fragments of silicified wood, but no leaf remains have been found.

It is probable that the gravel-beds mark the location of an ancient Dakota river. The lines of cross-bedding usually incline toward the southwest, indicating that the current came from the northeast, which agrees with our ideas of the origin of Dakota deposits. It is a matter of common observation that, while

wood is often fossilized in flowing streams, leaves are almost never preserved under such conditions. In fact, it has almost become a paleobotanical axiom that conditions which preserved leaves did not preserve wood, and *vice versa*. The theory that these deposits represent a river-bed seems strengthened by the fact that several exposures are found in a line extending northeast and southwest on both sides of the Platte, while "peanut rock" is not known in the group outside of the locality just described.

ECONOMIC PHASE.

INTRODUCTION.

The region of Dakota outcrops is by no means the most fertile in the states in which the group is located. The reasons for this fact are several. The country itself is usually too rocky to admit of cultivation, except in the valleys. Again, the soil is often rather light, owing to the presence of so large an amount of sand. The cultivated fields on the slopes wash badly, and in many cases have been permitted to revert to their original condition of grass-covered prairie. As a grazing country it has no superior in the West.

The rocks of the Dakota group, however, furnish a variety of products of economic value. These are distributed throughout the entire region, and are in many places a source of a very considerable income. These products will be discussed in the following order: Building stone, clays, coal, sand and gravel. More than ordinary importance will be attached to these products when it is remembered that in a prairie country, such as is occupied by the Dakota, materials of this character are comparatively rare. In not a few instances the Dakota is the only rock found. In such regions its products are consequently greatly enhanced.

BUILDING STONE.

The sandstone ledges so common in the Dakota are quarried in numerous localities in both Kansas and Nebraska. Nevertheless, in proportion to the amount of available material the Dakota is used to only a limited extent. The reasons for this are several. Of these, but two will be discussed in this connection.

First. As a rule the Dakota sandstone is not desirable building material. Representing all degrees of hardness from the very hard clay ironstone and quartzite-like rock, which is so hard as to turn the edge of the best tools, to the soft sand scarcely cemented together, the stone is either too hard to be dressed or too soft to resist weathering. Another objection is the absence of even fracture in the stone. Most of the ledges are cross-bedded, and, in quarrying, it is almost impossible to obtain anything like symmetrical blocks, the bedding plane being at all sorts of angles except right angles. Again, the color of the stone is often urged as an objection to its use for building purposes. The amount of iron in the various ledges even in the same quarry is rarely constant, and the irregular streaks and blotches of brown, red and yellow in the walls of buildings present anything but an artistic effect.

Second. With exception of the southern Kansas region and the Missouri locality, there is scarcely a place in the two states where either the Carboniferous, Permian, or Benton limestones do not outcrop within a few miles. Usually it is but a short distance to quarries of one or both of these formations, yielding excellent building stone. As the limestone is more easily worked, is more durable, and presents a more artistic appearance than the sandstone, it is often hauled within Dakota areas and even past quarries of Dakota sandstone. This may be observed in Cloud and Washington counties, Kansas, and Jefferson county, Nebraska.

Notwithstanding these facts, there are hundreds of buildings along the line of outcrops constructed of the sandstone. The group might be traced from Oklahoma to South Dakota by observing buildings alone. Stone fences, corrals, and foundations throughout certain sections are constructed almost exclusively of this material. But the use of the sandstone is not confined to the lesser structures. Dwellings, railroad depots, business blocks and schoolhouses are built of the Dakota. Some of the towns in which may be seen buildings of this stone are: Larned, Pawnee Rock, Great Bend, Ellinwood, Ellsworth, Kanopolis, Brookville, Glasco, Concordia, and Washington, Kan.; and Fairbury, Endicott, Beatrice, Lincoln, Ashland, Louisville, Tekamah, Homer, and Dakota City, Neb. If limestones were not so plentiful the number would be greatly increased. It is a noticeable fact that this sandstone is rarely shipped by rail.

There are, however, several localities in the group where valuable building stone may be obtained. The best of this stone is from the quartzite ledges mentioned under "Stratigraphy." So far as known, there are three outcrops of the quartzite, in widely separated localities in the Dakota. The quartzite-like boulders in the vicinity of Salina, Kan., and thence fifteen to twenty miles southeast, mentioned by Doctor Beede,⁵¹ will furnish an almost inexhaustible supply of the best of building material. The principal objection to its use is its extreme hardness, which only argues in its favor. The last time the writer visited Salina (in 1898), the quartzite near the old mill in the southeast part of the city was being removed for building purposes.

A ledge on Whisky run, five miles northwest of Fairbury, Jefferson county, Nebraska, is composed of very hard, gray, quartzite-like rock. The exposures occur along the sides of a ravine, and where seen were some four feet thick. The stone contains numerous finely preserved dicotyledons and wood fibers. There are also some pockets of iron pyrites, but scarcely enough to detract from the value of the material as a building stone. The rock from this ledge has been used in the construction of several farm buildings; but it is in bad repute among local stone-masons on account of its extreme hardness. It is the best building stone known in the state, and when developed promises to become an important economic factor. The hard ledge near Blackbird mission, on the Omaha reservation, mentioned by Doctor Hayden, is very like the Whisky run stone, but is not quite so hard. The old Presbyterian mission building, a large four-story structure, constructed of this stone fifty years ago, seems as solid to-day as when it was completed, and bids fair to stand for centuries. The ledges from which the rock was obtained are from one to four feet thick. Several other ledges along the bluffs back of Dakota City furnish rock of about the same character.

There is no reason why material from the quarries just described should not take the place of Wisconsin and Colorado stone in eastern Kansas and Nebraska. In appearance, durability, and general utility it is the equal of any that is being shipped into these states; and the supply is practically inexhaustible. Nothing is needed but the development of the quarries.

CLAYS.

Clays and shales occupy the greater part of the Dakota group. The term Dakota "sandstone," by which the group is known, is clearly a misnomer. The sandstones, being harder, resist denudation and by their uneven weathering give tone to the erosion forms throughout the Dakota area. It is rare that the clays and shales are to be observed when passing through the region of outcrops; while the sandstone ledges are everywhere conspicuous. The ledges of shale

51. Univ. Geol. Surv. of Kansas, 2: 291.

usually weather into gentle slopes, which are almost uniformly grass covered. It is only along the steep banks of streams or in artificial exposures such as railroad cuts that typical exposures of the clay may be seen. It is the opinion of the writer, after having studied the group in thousands of exposures, in four states, that at least two-thirds of the rock consist of clays and shales.

The character of this material is by no means constant. From a very arenaceous shale, with the prevailing yellowish-brown color, it grades through varieties less and less sandy; until finally in not a few places may be found dark-blue and almost black papyraceous shales and clays, resembling in lithological appearance those of the marine Kiowa. Between these two extremes of color are endless varieties and shades, with red, pink, yellow, cream and white predominating. Oftentimes all these colors may be seen in the same clay bank. Not infrequently thin, lenticular ledges of sandstone or concretions of various shapes and sizes are found embedded in the shale. These concretions, being normally of a dark reddish-brown color, and breaking with a conchoidal fracture, often render the slopes conspicuously brown. This clay is probably destined to become the most valuable economic product of the Dakota. The large and varied amount of iron contained in it, which causes the differentiation of colors, constitutes it a very superior brick and tile clay. The pottery products are also exceptionally fine.

In a number of localities brick-works which obtain their material from Dakota clay banks are in operation; and when experience shall have demonstrated the superiority of the products these plants can but increase. The sandstone of the Dakota, as has been shown, can never have more than a local value. Coal is limited in quantity and poor in quality, sand is found elsewhere, and gravel is not plentiful in this formation. The clay, on the other hand, being inexhaustible and of excellent quality, will be wrought more and more and the products shipped to distant localities.

The Yankee Hill Brick and Paving Company operates a plant three miles southwest of Lincoln, Neb., which may serve as a typical representative of the brick-works of the Dakota area. The clay is in this case obtained from a horizon a little above the middle of the group, probably about 100 feet below the Benton. Something like three acres are included in the bank, although the material in sight covers over 100 acres. Above the Dakota at this locality are some twenty feet of glacial drift and loess. From this material a certain kind of brick is manufactured. The following section, taken in a typical part of the bank, will indicate the sequence of the beds:

No. 6. Soil.....	5 feet.
No. 5. Loess	10 "
No. 4. Drift boulders and pebbles.....	2 "
No. 3. Yellowish, sandy clay, known as "bastard fire-clay".....	3 "
No. 2. Red, pink and white mottled clay	15 "
No. 1. Sleek, blue-gray clay shale.....	10 "

A hundred yards from the place where this section was taken the red and white mottled clay, No. 2, occupies nearly the entire thickness of the exposures; again, the yellowish fire-clay is more pronounced; while a quarter of a mile away, just over a small hill to the west and approximately on the same level, the clays have given place almost entirely to coarse, soft sandstone.

Experience has proven that a judicious mixing of the clays from the various horizons produces several different qualities of brick. The ordinary building brick is obtained by using two parts of the red mottled clay from No. 2 and one part of the loess, or No. 5; Nos. 1 and 2 in equal quantities make paving brick;

and the yellow clay from No. 3, treated by the dry process, makes a buff or cream-colored pressed brick superior to the Milwaukee product. The mottled clay when used alone produces a red and white mottled brick much in demand for ornamental fronts, and the clay from the same beds is used by the Lincoln pottery for the manufacture of its products.

Along the bluffs of the Big Sioux river, near Sioux City, Iowa, the clay between the Dakota and the Benton is excavated from a bank some sixty feet in thickness. In general, the clay at this locality is bluish drab or gray, and reminds one of the lower stratum at Yankee hill. Several companies are engaged in the manufacture of brick and tile at this place. At Sergeant's bluff, Iowa, nine miles below Sioux City, there are two plants engaged in the manufacture of brick. The material is obtained from a bank a quarter of a mile long, and in general appearance resembles the Sioux City clay. On the hill north of the Platte river, opposite Louisville, is a bank from which the clay is shipped to Omaha, and there made into brick and tile. At Beatrice, the material from the Dakota beds have been extensively manufactured into brick, as also have the clays obtained near Endicott. An enumeration of the localities containing available brick clay would simply be a catalogue of outcrops throughout the two states. There is scarcely a square mile of the Dakota that could not furnish sufficient clay to make brick to build a city.

COAL.

The coal of the Dakota group is inferior in quality and limited in amount. It is a lignite, or, as the popular phrase has it, "brown coal." This lignite is found throughout the group, from Oklahoma to South Dakota, ranging from the Permian or Comanche to the Benton. Knowing what we do of the conditions under which the deposits were made, we should be surprised not to find evidences of masses of decayed vegetation. In general, the conditions differed not materially from those that obtained in the Carboniferous age. The trunks and branches of trees, which in this case were dicotyledons instead of acrogens, blown down by the wind or swept away by the current, lodged in sheltered coves and were covered with sediment. These drift accumulations have since been converted into the lignite which is found today. The conditions have not been favorable to the production of harder coals, except in isolated and very limited areas.

Half a mile south of Bond's mill, Washington county, Kansas, several thin seams of lignite are found within a few feet of the underlying Permian. At the High banks, near Decatur, Neb., similar seams appear at the water's edge, probably about the middle of the group. In describing a bed of lignite near the mouth of Iowa creek, west of Sioux City, Doctor Hayden says that it is in the Benton, or at least in the transition between the Dakota and Benton, and that it is local or restricted in its geographical extent, and is the result of the accumulation of drift in the Cretaceous sea.

It is in the Smoky-Blue area in north-central Kansas, however, that the beds attain sufficient importance to be of commercial value. Even here they vary much in thickness. Some beds are two feet thick. Usually they are much thinner. Not infrequently the lignite is altogether wanting. It is found interspersed between beds of sandstone and shale, with often beds of carbonaceous shale near by. The horizon is usually from 60 to 100 feet below the Benton. The coal is most frequently obtained by stripping or removing the ledge near the surface. Occasionally shafts are sunk from the surface to the level of the lignite. These shafts are sometimes as much as seventy-five feet deep. Although the coal is of such poor quality, the price at the mouth of the shaft is usually as high as that of good coal in regions where the latter is plentiful.

Lignite is mined and used for fuel in Barton, Cloud, Ellsworth, Jewell, Lincoln, Mitchell, Republic, and Russell counties, Kansas. Some of the principal mines are at Wilson and Ben's Ranch, Ellsworth county; Coal cañon, Russell county; Elkhorn creek and Rattlesnake creek, Lincoln county; and Rock creek, Mitchell county. The supply is quite considerable and promises to meet the local demand for a number of years. That it will ever do more than this is scarcely to be expected.

SAND AND GRAVEL.

Like clay, sand is a constituent part of the Dakota. The supply is inexhaustible and the quality usually suitable for building purposes. As in the case of stone, however, there is often better material at hand, and the Dakota sand is not in great demand. As stated above, the region of Dakota outcrops is cut nearly at right angles by a number of streams flowing southeast. These streams ordinarily take their rise in the Tertiary, or at least flow across these formations, and for the most part have numerous low banks and sand-bars. The supply of sand for the larger towns, which are usually situated in the valleys, is obtained chiefly from these streams. In the Glacial regions the sand for building purposes is obtained from pockets in the drift. The Dakota sand is rarely so loosely cemented that it can be removed without the use of the pick; more often powder must be used to loosen the rock, which is afterward pulverized with the sledge. The drift sand, on the contrary, may usually be obtained with the shovel. An example may be cited at Lincoln, Neb., where the building sand is obtained from numerous drift pockets near the city, although there is in the vicinity plenty of Dakota sand, which would be used were the drift sand not more easily obtainable.

In not a few localities, however, the Dakota sand is utilized for building purposes. One of these is at Bennett, Neb., referred to above. A small outlier of the Dakota forms a cliff thirty feet high, surmounted by drift boulders. The sand is taken from the face of the cliff and utilized for general building purposes. A similar sand-bank is found at Tekamah, Neb., from which the sand is in places removed with the shovel, while only a few feet away it is so hard as to require blasting. The material from the Tekamah ledge makes a superior brick sand. In the vicinity of Beatrice, Neb., there are a number of Dakota sand-banks. One west of the Blue river furnishes 400 wagon-loads a year. Besides being used for building purposes, it has been utilized as molding sand by the Dempster Wind-mill Company.

Gravel is not common in the Dakota. The few localities in which it has been found are generally located in the hollows of the old Carboniferous floor upon which the younger Dakota has been deposited. These localities are invariably found near the eastern edge of the group. The most typical examples are seen on the Platte river, in eastern Nebraska, and have been discussed under "Stratigraphy."

The Cedar creek gravel-bed, which is, perhaps, the best known, was seemingly deposited in the channel of an ancient Dakota river. The material, which has been extensively excavated, is used by the Burlington & Missouri River railroad for ballast, riprap, fills, and foundations. The Missouri Pacific gravel-beds near Springfield, Neb., are very like those at Cedar creek. The supply in these localities is very considerable and will last for many years.

WATER-SUPPLY.

INTRODUCTION.

The Dakota is distinctly a water-bearing formation. The porous sandstone is capable of storing great quantities of water, while at the same time it offers very little resistance to its flow. Even the shales are in most places more or less

arenaceous, and usually permit the water to percolate throughout their entire thickness.

Springs are abundant in all parts of the group. It would scarcely be an exaggeration to state that there is an average of one spring for each square mile of Dakota territory from Oklahoma to Minnesota. Some of these are mere seepage springs, which cease their flow during dry weather, while others have a perennial flow. The springs of the group may be divided into two classes: fresh-water springs, and salt springs and marshes. The former occur indiscriminately in all parts of the formation, while the latter are ordinarily confined to the upper layers.

Something of the nature of the water in the various localities may be learned by noticing the names of the smaller streams throughout the regions of outcrops. In Ottawa, Republic and Washington counties, Kansas, and in Lancaster county, Nebraska, there are streams which have the characteristic name of Salt creek, and in Cloud county, Kansas, there is a Salt Marsh creek. In Ellsworth county, Kansas, Alum creek and Oxide creek bear testimony to the character of the water contained in them. All of these creeks take their rise in the region of the upper layers of the Dakota, usually near the Salt Marsh horizon of Logan. Saline river owes its name to the fact that it receives much of the drainage from these salt creeks. On the other hand, such names as Spring creek and Clear creek, which are by no means uncommon in the region, indicate that the stream is fed by fresh-water springs, usually from the lower beds.

ORIGIN OF DAKOTA WATER.

Three theories have been advanced to account for the water-supply of the Dakota. They may be designated as the artesian theory, the sheet-water theory, and the local-rainfall theory. It is proposed to outline briefly these three theories, and to draw from them such conclusions as seem warranted by facts.

Perhaps the chief exponent of the artesian theory is Mr. N. H. Darton, of the United States Geological Survey. Mr. Darton has spent a number of seasons in the field, in the plains and Rocky Mountain regions, and is entitled to speak with authority on the subject. In his excellent paper on the "Geology and Water supply of Western Nebraska,"⁵² he discusses the question of deep-seated waters, and touches on the subject of artesian water in the Dakota. It should be remembered that the Dakota sandstone passes under the more recent Cretaceous groups to the west. These later groups attain their maximum thickness in western Kansas and Nebraska, where the Dakota is probably more than 2000 feet beneath the surface. The greater part of this thickness is composed of Pierre shale, which is impervious to water. The sandstone of the Dakota, continuing westward, outcrops along the eastern slope of the Rockies and Black hills at an elevation of from 3000 to 6000 feet. The water, passing into the porous sandstone at these elevations, flows eastward beneath the Pierre shales, and has considerable pressure and head at a great distance to the east. In eastern South Dakota, the artesian wells, which yield a large amount of water, obtain their supply from the Dakota sandstone. The wells and springs of eastern Nebraska are thought to derive their supply from the same source. In this region, however, the pressure and head, which gradually decrease as the formation approaches the surface, have nearly disappeared. There are several springs in the region which are known locally as artesian springs.

"Sheet water" is a term which, in the states of the plains, is used rather loosely to indicate a steady and constant supply of well-water. The term is

52. Nineteenth Ann. Rept. U. S. Geol. Surv., pt. 4, pp. 719-785.

popular rather than scientific, and in this connection will be so used. In the Tertiary deposits of western Kansas, or the glacial material of eastern Nebraska, the so-called sheet water is usually found at the base of these surface formations, near the top of the underlying strata. The Cenozoic deposits, being for the most part composed of more or less porous clay, sand, and gravel, readily absorb large quantities of water, which gradually settles to the base of the formation till it finds a lodgment in a sand-and-gravel bed above an impervious stratum, the latter most often occurring at the line of unconformity with the subjacent formation. This, of course, means that the wells, in order to strike sheet water, must in most cases penetrate the entire thickness of the surface deposit.

Now it is very evident that the Dakota sandstone does not form a good floor for holding water. For this reason, if the subjacent strata be Dakota, the water, instead of remaining at the bottom of the Tertiary or Glacial, will readily enter the sandstone, which is ordinarily even more porous than the overlying rocks. It is to this sheet water, then, that many geologists look for the greater part of the water of the Dakota group.

There is little doubt that a considerable portion of the water-supply of the Dakota may be accounted for by the theories just discussed. It is difficult, not to say impossible, however, to believe that all the water in the group comes from either the Rocky Mountain region or from the sheet water of the Tertiary and Glacial. Mr. Logan recognized this fact and discussed the question at some length. Among other things he says: "It is not impossible that the source of a large part of the water is much nearer at hand than even the Tertiary formation. The Dakota sandstone is capable of storing a great quantity of water and of retaining it for a long time."⁵³

Two examples are given, illustrated by figures, showing that a comparatively small area of sandstone is capable of storing a sufficient quantity of water to supply a perennial spring. The most conspicuous example given by Mr. Logan is that of Terra Cotta mound, in the eastern part of Ellsworth county, Kansas. This mound is a solitary butte, consisting of 100 or more feet of shale and clay capped with a forty-foot ledge of sandstone. Although the sandstone is but a few acres in extent, a spring which flows from its base near the top of the shale is so strong that the water is carried through a pipe to a tank in a farmyard at the foot of the mound, where it furnishes sufficient stock water for the farm. It is evident that the water that supplies this spring either comes from the rainfall on the sandstone or else it is drawn up through the shale. Whichever solution is adopted the problem is not an easy one. It appears vastly improbable that capillarity or any other known physical force can draw this amount of water through such a thickness of shale; while, on the other hand, it would seem that the rainfall on a rocky point of not to exceed three acres, in a region where the annual rainfall is but twenty-six inches, is not sufficient to supply a never-failing spring.

One point on which the writer has attempted to inform himself, but with indifferent success, is that of the relative flow of springs in wet and dry seasons. Inquiries have been made concerning hundreds of springs with regard to the steadiness of flow. Many persons will assert that certain springs show no difference in amount from year to year, while others with equal opportunities for observation will declare that a marked difference in flow may be observed in wet and dry seasons. As far as my observation goes, some of the springs appear to

53. Univ. Geol. Surv. of Kansas. 2: 213.

have a steady flow, while others, perhaps the majority, are more or less intermittent.

There are, however, in the Dakota a number of springs, which can be accounted for by neither the sheet-water nor the artesian theories. They are usually located along the eastern margin of the outcrops, where the post-Cretaceous erosion has isolated buttes and ridges from the main body. A striking example may be found some fifteen miles southeast of Salina, Kan., where a narrow Permian ridge, half a mile wide and several miles long, is capped with fifty feet or more of the Dakota sandstone. At the base of the sandstone, along the east side of the hill, are a number of springs which flow all the year round. The water is evidently derived from the local rainfall on the Dakota ridge. Perhaps the best example of springs of this character may be found at Bond's mill, six miles west of Hanover, Kan. South of Mill creek, at this place, is a steep bluff 200 feet high, of which the upper part consists of Dakota. From the top of this bluff the country slopes gradually to the south, being more or less cut up by numerous deep ravines flowing to the east and west. At a distance of four miles south from the top of the bluff a gap has been worn down into the underlying Permian, completely isolating this area of Dakota, consisting of perhaps ten square miles, from the main body. Some of the finest springs in the Dakota region are to be found in this locality. Mr. Richard Bond, who located in the vicinity in 1858, assured the writer that the water from the spring which supplied his house showed no variation in the amount of flow in wet or dry seasons. The water must of necessity come from the local rainfall.

These facts appear to indicate that we may well look to all three sources discussed in this connection for the water-supply of the Dakota. While it is probable that a large amount of water comes from the mountains, and perhaps a still greater amount is sheet water, it can scarcely be doubted that in all localities the local rainfall helps to swell the volume, and is in many places the only source of supply.

FRESH-WATER SPRINGS.

The term "fresh-water springs" is used to include all the springs in the Dakota in which the water is not more or less salty. While in this connection it has no particular reference to what is usually known as soft water, still it is a notable fact that the water of the Dakota is unusually free from the various compounds of calcium that constitute hard water. Not infrequently the water has a taste not unlike that of rain-water. This is particularly true when the stratum from which it flows contains no clay.

It will be obviously impossible to mention but a very small per cent. of the thousands of springs which have been noticed in Kansas and Nebraska. At best, only a few, and those the most typical, may be referred to. In Kiowa county, Kansas, near the head of the Medicine river, in the locality west of Belvidere mentioned as yielding dicotyledonous leaves, there are numerous springs in a ledge of sandstone near the base of the Dakota. These are found chiefly on Spring creek and Little Rocky cañon, some ten miles south of Greensburg. In Clark county the best springs on Hackberry, Bear and Chapman creeks are from the Dakota. Near the base of the bluff washed by the Arkansas river, three miles east of Ford City, a spring issues so close to the water that it may only be seen when the river is low.

The area of the Dakota in northern Kansas is famous for both fresh and salt springs. In southern Ellsworth county, the creeks—Thompson, Oxide, Bluff, and others, which flow north into the Smoky Hill river—are fed by springs which issue from near the middle of the group; those at Burton's and Sher-

man's ranches being especially noticeable. At the noted cave section in eastern Ellsworth county there is a fine spring, the delight of picnic parties, for which the place is a famous resort. On the vertical cliff of sandstone above the spring may be seen Indian pictographs, which would seem to indicate that the aborigines were in the habit of frequenting the place. Unfortunately these hieroglyphics, which have so far escaped the ravages of time, are now being destroyed by visitors carving their names over the pictographs. This vandalism is the more to be deplored, because of the fact that the picture-writing, once destroyed, can never be replaced. It is but a few years at most until these records of a forgotten people shall have been obliterated. In Washington county, Kansas, where the Dakota has typical development, springs are abundant. Southwest of Washington, the county-seat, there are several that have a strong and persistent flow. Near Hollenberg, in the northern part of the county, springs issue near the base of the sandstone and supply the small streams which flow into the Blue river. Those on the farm of Jonathan Alden are worthy of special mention. Near Bond's mill, referred to above, along the bluffs south of Mill creek, there are dozens of springs that issue from the sandstone ledge near the base of the Dakota, immediately above the Permian. The water is, in some instances, piped for half a mile or more to farmhouses along the base of the bluff.

The largest area of Dakota in Nebraska, near Endicott and Fairbury, contains hundreds of springs. They flow into creeks which are tributary to the Blue. Those on the farm of Edward Case, a mile east of Endicott, are known throughout the country; while others on Whisky run, northwest of Fairbury, are nearly as strong. One of the most typical springs in the state is on the Robinson farm, a few miles south of Beatrice, where the water is carried in a pipe for half a mile, under a ravine and into a tank, where it furnishes an abundant supply for several hundred cattle. In the valley of Salt creek springs are abundant. On Haines branch, especially, salt- and fresh-water springs issue all along the bank for several miles. On the Platte river, from Plattsmouth to Ashland, of the hundreds of springs but one need be referred to. It is the one at the state fish hatchery, a short distance above South Bend. The spring issues from the sandstone in a deep ravine, and furnishes water for some thirty reservoirs in which the fish are bred.

From Blair to Tekamah, along the bluffs of the Missouri river, there is a continuous row of springs. Above Tekamah these become more frequent, and along the "bench road" between that city and Tekamah, a distance of sixteen miles, there are an equal number of strong springs, besides many smaller ones. In the following enumeration, beginning at Tekamah, the name given is either that of the owner of the farm upon which the spring is located, or else the local name by which the spring is popularly known: Shafer's, John Latta's, Rath's, Davis's, C. H. Johnson's, Marrow's, J. Laughlin's, Marsh spring, Stanton's, Golden spring, Landig's, Tippery's, H. Bussie's, A. White's, Decatur spring. Of these, Tippery's spring is known as an artesian spring, and is said to throw water to the height of sixteen feet. Golden spring has the strongest flow of any spring in the Dakota group, so far as observed. It has long been a famous stopping-place for freighters. Professor Capellini, in describing his trip from Tekamah to Sioux City, in 1863, gives an account of the spring, of which the following is a free translation:

"A spring of water, fresh and crystalline, is located half way between Tekamah and Decatur; on account of the color of the rock over which it flows it has received the name Golden spring (Source d'or). Some small shrubs surround it and give to the place a very picturesque aspect, and *Marchantia polymorpha*

growing along the sand covers that part of the rock over which the water runs in little rills."⁵⁴

Springs issue along the high banks above Decatur, and also near the mouth of Blackbird creek. At the old mission building, two miles north of this creek, there is a spring, famous long before the arrival of white men. At Homer, along the bluffs north and south of the city, there are some of the strongest springs known in the formation, and they continue past Ponca and as far up the river as the Dakota is found.

SALT SPRINGS AND MARSHES.

While the fresh-water springs of the Dakota are found in all parts of the group, the salt-springs, on the contrary, are ordinarily confined to the upper beds. Mr. Logan locates a salt-marsh horizon above the lignite horizon in his upper group, and describes it as follows: "Resting upon the lignite is a bed of shales which are, in the majority of instances, highly saliferous in character. They vary in thickness from ten to fifteen feet. By the disintegration of these shales, salt-marshes have been formed along the exposures of the upper Dakota horizons."⁵⁵

There are a dozen or more of these marshes in north-central Kansas, located in Lincoln, Mitchell, Cloud, Republic, and Jewell counties. In size they vary from a few square rods to several square miles in area. One in Cloud county is seven miles long, and, in places, a mile wide. They are usually found along the basin of one of the numerous creeks in the region, and are at nearly the same geological level—from 50 to 100 feet below the base of the overlying Benton. The marshes are flat and are covered with an incrustation of salt, sometimes a quarter of an inch thick. The water comes from numerous small seepage springs along the margin or on the bottom. The soil is permeated with this salty water, as may be demonstrated by digging a hole in the bank. This soon fills with salt-water which shows a density of from ten to twenty degrees on the salometer.

A description of one of these marshes will be good for a large number of them, as they are very similar in formation and appearance. The following, which is excerpted from a description made by Prof. B. F. Mudge in 1864, will, with a few minor modifications, answer for any one of a dozen marshes to-day. The marsh described is known as the Tuthill marsh, and is located in the southern part of Republic county, Kansas:

"The valley here is wide, gradually rising to the high prairies so common in that part of the state. The marsh covers nearly 1000 acres, more or less impregnated with saline matter. About one-third is entirely void of vegetation, which the brine will not allow to grow. It is perfectly level, and when first visited was as white as a wintry snow field, with a crust of crystallized salt. The marsh is of recent alluvial formation, composed of sand and loam from twenty to thirty feet in thickness, brought down by the wash from the high prairies, which gradually rise from three sides. The incrustation of salt is frequently three-eighths of an inch thick. The brine exists in nearly equal quantities and strength in all parts of the marsh, and can be obtained by boring a few feet. No definite salt-spring shows itself on the surface, but the supply must come from numerous points below."

The chief difference between this description and one made to-day would be in the size of the marsh. The increased amount of alluvium incident upon the cultivation of the adjacent region has so encroached upon the marsh as to materially lessen its area. Nevertheless, several hundred acres are still sufficiently saline to be without vegetation. Wells bored on land above the common level furnish brine which flows from the top of the well out over the marsh. On Salt

54. *Memoires de la Societe Helvetique des Sci. Nat.*, vol. XXII, No. 1, p. 5.

55. *Univ. Geol. Surv. of Kansas*, 2: 209.

creek, in southern Mitchell county, there is a large marsh that formerly contained 3000 acres. In the same region are some springs of salt-water which issue from beds of sandstone, evidently the salt-marsh horizon, which outcrops fifteen feet or more above the level of the creek. Great Spirit spring, near Cawker City, owes its saline properties to the fact that its waters are derived from this horizon.

The salt-marshes at Lincoln, Neb., are very similar to those in northern Kansas. They are located in the valley of Salt creek, near the western outskirts of the city of Lincoln. Several branches of Salt creek converge near by, forming a broad and nearly level bottom, containing several thousand acres. Over this bottom the salt flats or marshes are scattered for several miles up and down the creek. The small streams which converge near Lincoln all contain fresh water except one. Haines branch, which flows from the southwest, contains along its lower course hundreds of salt-springs, not dissimilar to those described from Mitchell county, Kansas, except that they issue from mud banks near the water, instead of from the sandstone at a higher level. This may be accounted for by the fact that in the vicinity of Lincoln post-Cretaceous erosion has removed the sandstone.

In general appearance these marshes are so similar to those in Kansas that, on casual examination, no marked difference can be observed; both have the same flat surface, salty incrustations, and seepage springs near the margin and on the bottom. The strength of brine varies little, and in early days salt was obtained for commercial purposes from either locality. Both occupy the same general horizon, from 50 to 100 feet below the Benton, and the character of the rock from which the salt-springs take their rise is practically the same. Near Lincoln, as in Kansas, many of the wells in the Dakota yield salt-water. An example may be cited at the Yankee Hill brick-works, southwest of Lincoln.

Doctor Hayden considered it probable that the salt-water of these marshes came from the Carboniferous shales, which in this vicinity are found at a depth of some 270 feet. The same author, however, considered that the Kansas marshes derived their supply from the same horizons. Later geologists are divided on the question, some contending for the Carboniferous, others for the Dakota age of the salt. One fact that gives much credence to the position of those who look to the Carboniferous for the source of supply is that the shales of this age immediately below the Dakota are highly saliferous and the water contained in them has a strong artesian flow. This fact, together with another condition which seems fairly well authenticated, viz., that the entire thickness of the Dakota in the vicinity consists of porous sandstones, with scarcely a trace of clay or shale, has been sufficient to establish the theory of Carboniferous origin. Other investigators have pointed out the similarity of these marshes in general appearance and geological position to those less than 100 miles away, in which the salt comes from undoubted Dakota horizons, and have drawn the inference that the salt-marshes at Lincoln and in Kansas must be similarly accounted for.

To the writer it appears probable that one who had studied the conditions in the vicinity of Lincoln alone would be most likely to assign the origin of the salt to the Carboniferous. On the other hand, the geologist who had previously observed the conditions in other parts of the Dakota area, particularly in northern Kansas, would not be wrong in considering the saliferous shales of the upper part of this group as the true source of the salt in the Lincoln salt-marshes.

WELLS.

It is natural to suppose that a formation containing so many springs as does the Dakota would also furnish good well-water. This is almost universally true.

As has been remarked, the Dakota is the most important water-bearing bed of the plains, both on account of the quality and quantity of the water. Whatever theory we may adopt to account for the origin of the water, its presence, abundance, and purity are axiomatic. The amount of well-water that is utilized from the Dakota is probably greater than that of the spring-water. Wells begun in this formation usually find water in abundance at a depth of from ten to forty feet. In the overlying strata the depth to water depends on the thickness of these deposits, the flow being encountered at the line of unconformity, or, if the Dakota, at that particular spot, consist of sandstone, at a short distance below that line. The probability of water being found in the Dakota is so great that, in order to estimate the depth of a well in any locality underlain by this group, it is only necessary to know the thickness of the overlying deposits. Advantage is taken of this fact in preparing water maps of the various regions. One of the best of these is by N. H. Darton,⁵⁶ in which the "depths to Dakota sandstone, which usually yields abundant water-supplies" is graphically represented in colors. Such a map might well be prepared of the entire line of Dakota outcrops and would be of extreme economic as well as scientific value.

As in the case of springs, the wells of the Dakota may be divided into fresh- and salt-water wells. The former so universally predominate, however, as to be understood, unless the others are specifically mentioned. Salt-wells in the Dakota are ordinarily found only in the vicinity of salt-springs and marshes, particularly near Lincoln, Neb., and in north-central Kansas. The water in few of these wells is sufficiently saline to prevent its use, although in a few cases this phenomenon has been recorded. The water-supply of but one of the several artesian basins in Nebraska can with certainty be referred to the Dakota. This is the northeastern basin, in Knox, Cedar and Dixon counties. This region is in reality a continuation of the James and Missouri river artesian basin of South Dakota. The wells in this part of the state find artesian water at a depth of from 300 to 600 feet. The deep artesian wells at Lincoln and Beatrice pass through the Dakota and find their supply in the Carboniferous, at a depth of from 300 to 2000 feet.

One rather interesting fact connected with Dakota wells should, perhaps, be noticed here. It often happens that a farmer whose buildings chance to be situated in a Permian valley near a Dakota hill fails to obtain a sufficient supply of water by digging. Or it may be that the water which he finds is so strongly impregnated with gypsum or other salts which permeate the upper beds of the Permian that it is not fit for use. Not infrequently, after having sunk several wells in the vain hope of obtaining a sufficient amount of good water in the valley, in despair he puts down a well on the top of the hill, in the Dakota sandstone. In such a case he often surprises himself and his neighbors by obtaining an abundant supply of the best of water. Instances of this kind are often pointed out to the itinerant geologist as freaks of nature. The reasons for the phenomenon are obvious.

ECONOMIC VALUE OF WATER.

The region of Dakota outcrops is distinctively a grazing country. Except in the valleys of the larger streams, or on the uplands where the sandstone is covered by later deposits, the greater part of the area is devoted to cattle raising. The sandstone hills produce the most nutritious grasses in the greatest profusion. Thousands of cattle are annually shipped to these ranges from the west, fattened during the summer, and in the fall sent to eastern markets. Some of

56. Water Sup. and Irriga. Papers, U. S. Geol. Surv., No. 12, pl. xvii.

the largest ranches in the two states are in this region. As examples may be cited the Fullington ranch, in Kiowa county, Kansas, which extends for fifteen miles along the Medicine river, or the Sherman ranch, in Ellsworth county, which contains 65,000 acres.

In most places the question of stock water is of paramount importance to the ranchman. It often occurs that cattle raising in a certain locality is not profitable simply on account of the scarcity of water. There is a saying on the plains: "The man that controls the water controls the country." This problem, so vexing in many regions, solves itself in the Dakota areas. The great abundance of water from the numerous springs is usually adequate for all purposes. Very often it is not necessary to give the matter the least attention. The water from several springs unites to form a creek, to which the cattle resort. But if running water is not sufficiently plentiful, the ranchman lays a pipe from a spring on the hillside to a tank. Hundreds of these tanks may be noticed in the pastures of the two states. In not a few instances the water from a good spring will be carried to the house, through the kitchen, through the milk-house, and finally to a tank in the barn-yard, supplying sufficient water for all purposes. The farmer's wife has the advantage over the city woman of knowing that the water she uses is pure.

In former years the salt-marshes of Kansas and Nebraska were a source of revenue to hundreds of persons annually. It is stated that at one time there were several hundred "squatters" located on the salt-basin area near Lincoln, all engaged in evaporating brine. Salt for local purposes was procured in Kansas by dissolving the salt incrustations which covered the marsh, in order to allow the impurities to settle, and afterward reevaporating the brine. The discovery of the magnificent salt beds in the middle Permian of central Kansas has put an end to these cruder methods of production, and it is very improbable that they will ever be renewed.

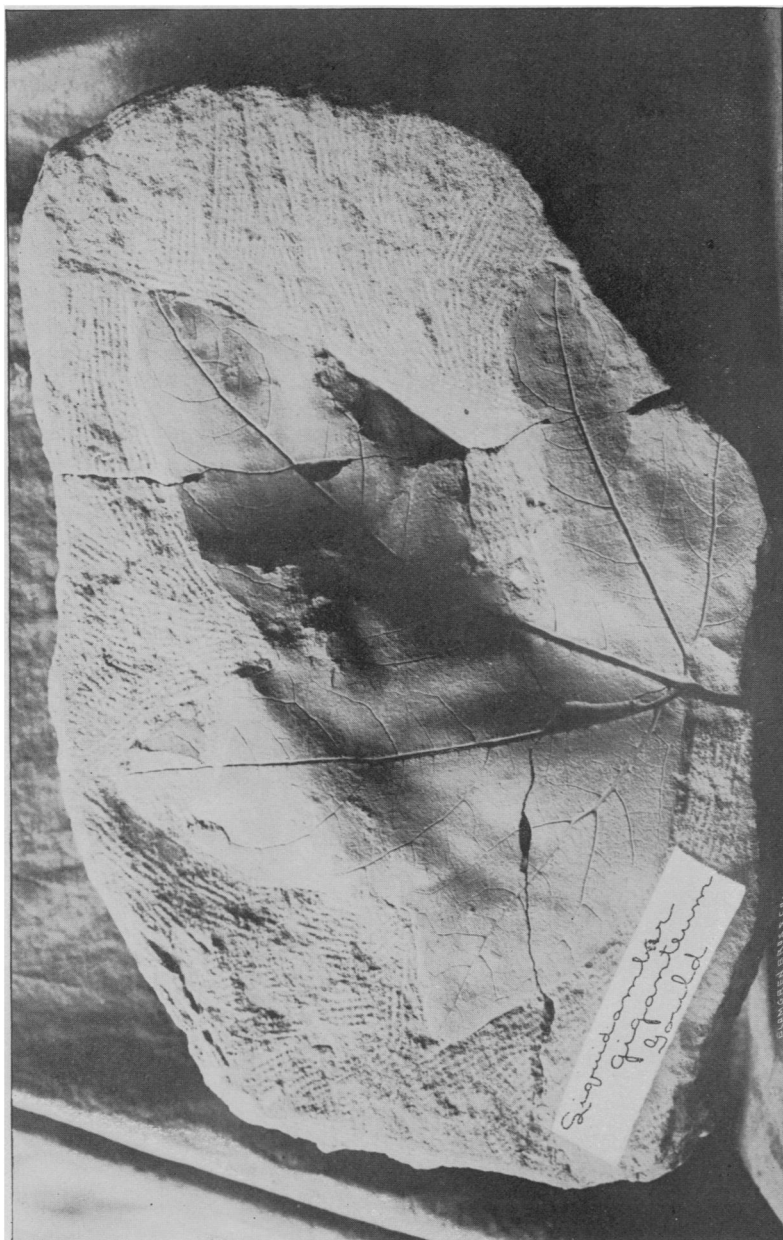
The chief economic value of the Dakota water, however, lies not in the salt-water of its marshes. The thousands of springs, and tens of thousands of wells, in the area of the outcrops of this group witness daily to the importance of water as an economic factor. In such states as those of the plains, where agriculture is and always will be the chief industry, the question of water-supply is paramount; and the Dakota, being the great water holder of the plains, can scarcely fail of recognition in the various problems that are to be worked out concerning the ultimate water-supply of these states.

PALEONTOLOGY.

PLANTS.

While invertebrates are rare, and vertebrates are almost wanting, in the Dakota group, fossil plants are almost universally present. So common are they that their presence usually excites little curiosity among the farmers and ranchmen living along the line of outcrops. There is scarcely a hill or even an exposure of the sandstone in the Dakota area that does not yield at least fragments of leaves. These fossils are in all states of preservation, from mere traces of nervation to perfect impressions. They vary in size from the tiny *Betulites westii*, scarcely more than a centimeter in diameter, to the magnificent *Sassafras giganteum*, which measures forty centimeters from lobe to lobe.

Of necessity, only impressions of these leaves remain. The vegetable material has long since disappeared, and the most delicate chemical tests, even on those leaves that seem to retain some traces of carbonaceous matter, fail to reveal the presence of either lignin or cellulose. Ordinarily the color of the fossil is the



Liquidambar giganteum Gould, one of the new species of Dakota leaves in the museum of the University of Nebraska.
Photo by Edholm.

same as that of the sandstone in which it is embedded, usually a yellowish brown. Not infrequently, however, especially in the quartz-like rocks, the impressions are almost jet black, and stand out in bold relief to the gray stone. It often happens, especially where the leaves have been enclosed in concretions, that the exposed surface has been polished by the action of the wind and rain until it presents a sleek, glossy appearance. Again, in the softer sandstones the impressions are so fragile that they crumble on exposure, and can be removed, if at all, only with the greatest difficulty.

The history of the subject has been discussed under its proper heading, and only a brief résumé can be given here. The three men who, more than all others, have contributed to our knowledge of the paleobotany of the group are Oswald Heer, J. S. Newberry, and Leo Lesquereux. Professor Heer, of Zurich, Switzerland, was probably the most noted paleobotanist the world has ever known. His knowledge of fossil plants was profound and comprehensive. He described forms from many parts of the world, more especially from Europe and the arctic regions. His connection with the history of the Dakota group is confined to the identification of two collections of plants. The outline drawings of specimens sent him by Meek and Hayden in 1858 were referred by him to the Tertiary, and his position was afterward defended in a series of letters in the Heer-Newberry controversy. Professor Heer also described the collection made by Marcou and Capellini in 1863. The leaves were figured in the paper "*Phylites Crétacées du Nebraska*," which is the first printed description, with plates, of Dakota leaves.

Dr. J. S. Newberry, the eminent American geologist, also did much good work in Dakota phyt paleontology. He first identified the leaves of which drawings had been sent to Professor Heer as Cretaceous forms, and enunciated the dictum, which has since been universally accepted, that the essential facies of the Dakota flora did not differ materially from that of the present time. Several papers of importance from the pen of Doctor Newberry were published during the '50s, but owing to a misunderstanding with Doctor Hayden he ceased to interest himself in the subject.

It was Leo Lesquereux, whom Doctor Knowlton justly styles the Nestor of American paleobotanists, who did more than any other man for the cause of the phyt paleontology of the Dakota group. Leo Lesquereux is perhaps the most pathetic figure in American science. Practically exiled with Agassiz and Guyot from his native land at the age of forty years; totally deaf, so that he never heard a word of spoken English; living alone among strangers in a strange land; his whole life filled with hardships and disappointments: nevertheless at his death America lost not only her most distinguished vegetable paleontologist, but also her foremost bryologist. The amount of work he performed was immense; and the record of his achievements will long stand as a monument worthy the emulation of future generations. Doctor Hayden, who made most of the early collections of Dakota leaves, submitted a number of specimens to Doctor Lesquereux for identification; and in 1868 his first publication on the subject appeared. He was at this time sixty years of age. From this date until the time of his death, in 1889, scarcely a year passed that he did not present to the scientific world a contribution to the knowledge of this most interesting subject. The three most important of these publications are: *Cretaceous Flora*, published in 1874; *Cretaceous and Tertiary Floras*, in 1883; and *The Flora of the Dakota Group*, in 1892. This last is Doctor Lesquereux's masterpiece, and was incomplete at the time of his death. The book was edited by Dr. F. H. Knowlton; and the careful manner in which the work was done testifies to the scholarly attainments of the editor.

In regard to the geographical distribution of the flora, it has already been stated that the leaves have been found in every locality that contains Dakota outcrops, and at almost every exposure. They have been collected west of Belvidere, in Clark county; on Bear creek, in the extreme western part of the state; and along the Arkansas river, at Great Bend, Pawnee Rock, and Larned. The region which has yielded not only a greater variety of forms but also a greater number of specimens than any other is also the region in which the Dakota reaches its best development, viz., eastern Ellsworth county, Kansas. This is the famous collecting ground of Mudge, Snow, West, and Sternberg. Leaves are found on Bluff, Thompson, and Oxide creeks, south of the Smoky Hill river; and on the north side, near the towns of Kanopolis, Ellsworth, Carneiro, and Terra Cotta, they may be collected on every hill. Near Brookville and Tescott there are prolific localities, as also in the vicinity of Minneapolis and Glasco. One of the finest collecting grounds known is at Bond's mill, in Washington county, Kansas. From this point leaves are found as far northwest as Fairbury, Neb. Doctor Lesquereux reports leaves from Beatrice. The outcrops of Dakota near Lincoln furnish a few rather poor specimens. Along the Platte river some fairly good leaves have been found. The bluffs of the Missouri from Omaha to Sioux City yield some good leaves, especially points near Tekamah, Golden spring, Decatur, and Blackbird hill, Neb., and Sergeant's bluff, Iowa.

It may not be ill advised to mention in this connection the increase in the number of known species from time to time. Professor Heer, in his "*Phyllites Crétacées du Nebraska*," discusses seventeen species; in Doctor Lesquereux's first paper, in 1868, fifty-three new forms were mentioned: while in 1874, at the time of the publication of his "*Cretaceous Flora*," the number had been increased to 130. In his "*Cretaceous and Tertiary Flora*," in 1883, 190 species are mentioned. The discovery of the magnificent leaf beds in Ellsworth county so increased the number of forms that, when Doctor Lesquereux began his "*Flora of the Dakota Group*," in 1885, 350 species were known; and the addition of 110 forms from the collections of Sternberg brought the number up to 460. Of these, six are ferns, twelve cycads, fifteen conifers, and 429 dicotyledons. The latter class forms over ninety per cent. of the entire series. Since the appearance of "*The Flora of the Dakota Group*" comparatively little work has been done on the paleontology of the Dakota. Hollick, Ward, and others have described a few new leaves, probably less than a score of species in all. The collections made in Kansas in 1897 and 1898 by Dr. Lester F. Ward and the writer, and in Nebraska, by the writer, in 1899, have yielded a number of new forms, the greater part of which are now in the museum of the University of Nebraska. (See plate XII.)

In the discussion of the stratigraphy of the group it has been shown that there is no continuity of strata in the Dakota. Sandstones and shales are stratified indiscriminately with clays throughout the formation. This of itself points to changing conditions of sedimentation. It was this marked peculiarity, as well as the manner in which the leaves were deposited, that led Doctor Lesquereux to adopt his views of the manner of deposition of the Dakota, which are now almost universally accepted among students of the group. It is unnecessary to reiterate the statement that, in the main, the opinions of the writer coincide with those of Doctor Lesquereux. For this reason (and even at the risk of being thought to quote too fully), the following paragraphs from this noted author are herewith given. They represent his latest thought, having been written after he had worked over the last collection of Sternberg, shortly before his death:

"In my '*Cretaceous Flora*' the question concerning the probable derivation of the numerous vegetable remains found in the shaly sandstone of the Dakota

group, their mode of deposition, etc., have been examined. From the facies and the peculiar distribution of the leaves, it is there admitted that the vegetable remains have been derived from trees or shrubs growing in the vicinity of marshy or muddy bottoms, and that they have been buried or fossilized at or near the place of their growth. This condition is based not only upon the remarkably good state of preservation of the fossil leaves, which are generally found horizontally flattened in the same plane or parallel to that of the deposition of the earthy matter, neither crumpled, rolled, nor lacerated, and with their borders, often even their petioles, attached to them, but also upon the distribution of the leaves, which at different localities generally represent different species, while at a short distance another group of leaves represent other species, genera, or even families.

"These remarks have been lately confirmed by the discovery in Ellsworth county, Kansas, of a very large number of leaves embedded in concretions. These concretionary specimens were found at more than twelve different localities, in groups covering limited areas, the largest tract being about 100 yards, the others not more than seventy yards in width, altogether distributed over a land surface of five to eight square miles. The specimens of each locality were separately collected and were also determined separately, and each lot was found to be composed of from one to three species, and few of them were represented in more than two or three localities. Thus, leaves of *Sterculia* were found in one locality; at another, leaves of *Greviopsis*; in two or three others mostly leaves of *Betulites* were collected; and in others leaves of *Populus kansana*, with *Diospyros rotundifolia*, etc. The leaves forming the nucleus of the pebbles are in a perfect state of preservation, a number of them with their pedicels, or even a small stipule at their base. Of course the fossilization of numerous leaves of the same species in groups, at various more or less distinct localities, gives positive evidence of their growth in that place, or at least quite near, where their remains have been fossilized.

"As yet the relative altitude of the localities where the various groups of specimens have been found has not been fixed, and we do not know whether the diversity of the characters of the plants might not be accounted for by a difference in the horizon of the strata where they have been found, and therefore by a difference of age. Are there peculiar zones in the formation, which might be indicated by marked characters in the vegetation? No answer can as yet be given to the question. The concretionary specimens mentioned above have been found in the so-called highlands of Ellsworth county. But what are those highlands as compared in altitude to the lowlands? Professor Mudge, who has closely searched for the distribution of plants in Kansas, did not find any difference in the character of the plants that seemed to depend on the altitude of the hills. Near Salina I have found the same vegetable species distributed from the base to the top of the hills, the altitude being about seventy-five feet above high-water mark of the river. Hence, it is not possible as yet to consider a difference in the vegetation by peculiar zones like those in the Quadersandstein or Middle Cretaceous of Europe, where zones of the *Liriodendron* or those of the *Crednaria* are mentioned as marking the relative horizons of the strata."⁵⁷

To this it is but necessary to add that later investigations have but corroborated the conjectures of Doctor Lesquereux. Certain genera and species are confined to restricted localities, while others are found in widely separated regions. *Proteoides daphnogonoides*, for example, was one of the species described by Heer in his "Rhylites"; but it has since been found in nearly every locality and horizon throughout the group. *Salix proteaefolia* is another form that is widely distributed. On the other hand, *Betulites*, *Protophyllum*, and many others, although very abundant in certain localities, have never been found elsewhere. *Platanus*, *Sassafras* and *Liquidambar* have been found more abundantly near the base of the group, while *Liriodendron*, *Juglans* and *Aralia* seem to be more common in the upper part. These observations, however, may be simply coincidents; and no particular importance need be attached to them. That a determination of phylogeny of species, if not of genera, in the Dakota group is desirable goes without saying; and the writer confesses to a hope that

57. Flora of the Dakota Group, U. S. Geol. Surv., Mon. No. XVII, pp. 20-22.

this will eventually be demonstrated. He has constantly kept the matter in mind during the last three field seasons; but at the present time is reluctantly forced to admit that any evidence of plant development from the lower to the higher beds of the Dakota is practically wanting.

That development is shown throughout the various Cretaceous groups, however, may scarcely be doubted. The Cheyenne sandstone, 200 feet below the base of the Dakota, contains a flora which, in general appearance, resembles that of the Amboy clays, or the Tuscaloosa formation, which represent practically the oldest dicotyledonous flora known. The types from these horizons show much less of development than those found in the Dakota. The Laramie flora, which is obtained from beds some 2500 feet above the Dakota, shows considerable advance over the Dakota forms.

The average life of a tree is measured in hundreds of years; that of a marine invertebrate will perhaps not average more than twenty years. As trees are longer lived, so their forms change more slowly in response to environment than animals. The invertebrate fauna of the Cretaceous changes several times from the Cheyenne to the Laramie. A number of forms found in the Champion shell-bed, a narrow horizon at the base of the Kiowa, do not appear higher in the formation. The fauna of the Mentor beds, at the base of the Dakota, is quite different from that of the upper Dakota beds, which resemble the Benton fauna. By the time the upper Cretaceous groups are reached the fauna has again changed. Certain species of plants, however, persist from the Cheyenne to the Dakota, and yet others from the Dakota to the Laramie and even almost to the present time. When the flora of the Cheyenne sandstone shall have been worked up, it should not be thought surprising if it is found that in that formation there are species identical with the Laramie or even later groups. While these statements are true, it by no means argues that the flora as a whole, or even any considerable part of it, is found in different groups. Only a few species, comparatively speaking, persist for any great length of time. Each group is represented in a large degree by forms which are characteristic of it, and are found nowhere else. That plants are more tenacious of life than animals is shown by the fact that there are few genera of fossil plants, even of those as far back as the Dakota, which are not represented in recent floras. A few genera, however, such as *Protophyllum*, *Aspidiophyllum*, and some others, seem to have no affinities among living plants. Either their essential characters have been gradually effaced by rapid modifications, and so intimately mixed with others as to become unrecognizable, or they have been unable to adapt themselves to changed environment and have become extinct.

It is a lamentable fact that plant paleontology has fallen into ill repute both among geologists and botanists. The reasons for this are, perhaps, in many cases legitimate. The botanist, particularly, having before him all parts of living plants—root, stem, leaf, flower, and fruit—is apt to look askance at the work of the paleobotanist, who at best has but one of these organs, and that often in an imperfect state of preservation. He argues; and apparently with reason, that the inferences drawn from such fragmental data are at best imperfect, and consequently misleading; and for this reason is prone to cast aside the work of the paleobotanist as of no permanent value. The botanist is right in considering that a single fragment of a leaf in an indifferent state of preservation is scarcely sufficient data on which to found a new species; nor should he admit that slight variations in the form, margin or nervation of leaves constitute specific differences.

The paleobotanist, on the other hand, insists that while much of his work is of necessity incomplete and must be revised in the light of later discoveries,

nevertheless the greater part of it has permanent value. Notwithstanding the fact that the fossils with which he works are extremely unsatisfactory, still there remains a great mass of material which is not only of extreme general interest but also of positive value in determining the age of the rock in which it is found as well as the phylogeny of the plant forms. These statements are ordinarily accepted with more or less of reservation by investigators along other lines.

It is possible that this undesirable condition of affairs has arisen partly from a misunderstanding of terms and partly on account of the methods employed by the paleobotanist. During the early history of this science, as of all others, vegetable paleontologists were too often content with simply multiplying species rather than in working out the phylogenetic problems of plant life. Much of the work will stand; while a great part of it must eventually be revised, as the work of the older botanists has been revised. The work along paleogenetic lines could scarcely have been done earlier because of insufficient data; but the time has arrived when, if paleobotany is to keep pace with other sciences, this vital point may not longer be neglected.

The terms "species," as employed by the botanist and by the paleobotanist are not to be considered synonyms. This fact was tersely stated by Mr. Lesquereux in his first paper, in 1868, as follows: "It is well understood that when the word 'species' is used in an examination of fossil plants it is not taken in its precise sense. For, indeed, no species can be established from leaves or mere fragments of leaves. But as paleontologists have to recognize these forms described and figured, to compare them and use them for reference, it is necessary to affix to them specific names, and therefore to consider them as species."

In other words, the term "species," as it has been employed by paleobotanists, is little more than a convenient handle with which to manipulate certain more or less identical forms. No one who has given the matter any attention can be unaware that the identification of species from leaves alone is in many cases impossible. Leaves of a dozen species of living willows, for example, are so similar in nervation and outline that, if mixed up, they could not afterward be referred to their proper species by any living botanist; while, on the other hand, a dozen leaves taken from the same cottonwood tree might be placed in half that number of different species.

The identification of fossil leaves rests chiefly upon two points: form or outline, and nervation. Of these, nervation is generally considered as determining generic, and outline specific, differences. That these points obtain for some plants appears reasonably demonstrated; but their universal application remains to be proven. The subject of the nervation of dicotyledons has never been worked out, save in a general way, and it is one of vital importance to the science of paleobotany. In view of these facts, then, it would seem that until this question is settled the continued indiscriminate naming of new species on slight and often fancied variations in form or nervation can only add to the apparent confusion into which the science has fallen.

It is not deemed expedient in this connection to enter upon an extended discussion of the genera and species of the group. "The Flora of the Dakota Group" contains practically all the forms so far recorded, and to it the reader is referred for details.

INVERTEBRATES.

The invertebrates found by Professor Mudge in Saline county, Kansas, and considered by Meek and Hayden as representing Dakota forms, are now generally conceded to belong to the Comanche series. The "Mentor beds," as these horizons were termed by Professor Cragin, are now considered as the northern

limits of the Kiowa shale, representing, probably, the extreme limits of the Belviderean sea at the beginning of the Dakota epoch.

The first collection of fossils from this locality contained twelve species. From time to time additions have been made to this number, until probably fifty species have been recognized from these beds. The fossils have all been found in the lower part of the Cretaceous of the region, probably all within 100 feet of the Permian. Above these horizons no more shells are found in the Dakota until the upper layers are reached. Meek and Hayden mention three invertebrates found near the mouth of the Big Sioux river, and a few additional species have since been found in the same locality. Professor Hicks discovered a locality in Jefferson, county Nebraska, from which Doctor White identified seven species. During the summer of 1889 the writer discovered two localities in the upper part of the Dakota from which shells were obtained. One of these is near Glasco, Kan., and the other at Jackson, Neb. The horizon of these widely separated localities is practically the same, being about fifty feet below the base of the Benton. The shells were submitted to Dr. T. W. Stanton, our best authority on Cretaceous invertebrates, and were referred by him to a number of species hitherto found in either the Big Sioux or the Jefferson county localities. Doctor Stanton states that the shells from the Mentor have not been found in the upper layers of the Dakota, and *vice versa*, with the possible exception of some species of *Ostrea* of which the identification is uncertain.

Mr. Logan, however, reports species from the upper beds which are also found in the Mentor. The following quotation is from Mr. Logan's paper: "In the upper Dakota group fossils have been found in three horizons. In the thin sandstone layers of the first shale bed the following fossils were found." [Then follow the names of fourteen shells.] "In the saliferous-shale horizon was found a bed of fossils, of which the following have been determined. . . . Altogether, more than twenty-five species have been found in the Dakota."⁵⁸

Of the shells mentioned by Mr. Logan, at least eight have been recorded as occurring in the Mentor, either in Saline county or near Marquette, while several are among those which have been found only in the upper part of the group. The writer makes no pretensions to a knowledge of invertebrate paleontology, and consequently disclaims the ability to intelligently discuss the question.

VERTEBRATES.

The paucity of vertebrate fossils in the Dakota has long been a matter of note. As late as 1898 Doctor Williston said: "No vertebrate remains of any kind have so far been discovered in Kansas or elsewhere, save some impressions or casts. A record of footprints from this formation was first made by Prof. B. F. Mudge in 1866, and a later one by Prof. F. H. Snow."⁵⁹

The tracks described by Professor Mudge were found by him in the valley of the Republican river, about fifty miles from its mouth. The slab containing the prints was lost at the Kansas agricultural college. It is but just to say that the vertebrate origin of the prints has been questioned, and Professor Mudge himself was led to believe that they were the work of Indians.

The track described by Professor Snow was secured on Thompson creek, Ellsworth county, Kansas, in 1885, by Judge E. P. West.⁶⁰ The horizon from which the specimen was taken is about the center of the group. The slab containing the track is now preserved in the museum of the Kansas university. The impression is evidently avian in character, and has been so regarded by vertebrate paleontologists.

58. Univ. Geol. Surv. of Kansas, 2: 212.

59. Loc. cit., 4: 50.

60. Trans. Kans. Acad. Sci., 10: 3.

Since the statement of Doctor Williston, quoted above, two vertebrate fossils have been found in the Dakota. Prof. C. S. Parmenter has recently described a fossil turtle found south of Concordia.⁶¹ The fossil cast is composed of the characteristic red sandstone. It is eleven inches long, nine inches wide, and contains the well-defined impressions of fourteen ribs.

On August 27, 1899, the writer found, at the High banks along the Missouri river, a mile above Decatur, Neb., a reptilian vertebra. The fossil was found embedded in a bank of yellowish clay near the water's edge. The centrum of the vertebra is 70 mm. long, 55 mm. wide, constricted to 35 mm. in the middle, the ends being but slightly concave. Doctor Williston, to whom the fossil was submitted, was unable, on account of its imperfect state of preservation, to identify it with certainty, but considered it the vertebra of either a crocodile or a dinosaur.

CONCLUSION.

The Dakota Cretaceous as a group is widely but not thoroughly known. Its history dates from 1804, when Lewis and Clarke first described the hills of soft, yellow sandstone near Sioux City. The controversy concerning the age of the group, waged by Meek, Hayden, and Newberry, against Swallow, Hawn, Marcou, and Heer, occurred from 1855 to 1864. The men who have written most extensively concerning the group, besides those just mentioned, are White, Ward, Hay, Mudge, and especially Leo Lesquereux.

The Dakota extends from southwest Kansas to northeast Nebraska, along a line over 500 miles long. The region of outcrops along this line approximates thirty miles in width. It reaches its greatest development in central and northern Kansas. To the northeast and southwest of this region post-Cretaceous erosion and deposits have so modified the Dakota that the outcrops are usually restricted to lines of bluffs or isolated exposures.

The rocks of this group rest either conformably on the Comanche Cretaceous, or unconformably on the Permian or Carboniferous. The line of demarkation between the Comanche and the Dakota has not been sharply drawn; and, in the light of our present knowledge, such a line is impracticable. The Dakota grades upward into the Benton wherever the latter is present; otherwise the upper limit is marked by a line of unconformity below Cenozoic rocks. The stratigraphy of the group has not been well understood. Instead of consisting almost exclusively of sandstone, it is found that the greater part of the entire thickness is composed of clays and shales. There is no general continuity of strata, the various members appearing and disappearing without seeming regularity. The origin of the rock is probably estuarine or beach deposits under changing conditions of elevation. Besides the ordinary forms of stratigraphy, many peculiar phases may be observed, such as concretions, gravel-beds, quartz-like ledges and the like.

The stone of the Dakota is used for building purposes to only a limited extent. The clays, however, are destined to become an important economic factor. An excellent quality of brick and tile has been manufactured from this clay in several localities. Coal is mined in limited areas in northern Kansas, but is inferior both in quality and quantity. Sand is plentiful but is not in great demand. The few deposits of gravel in the formation are being utilized by railroad companies.

The water-supply is inexhaustible. The Dakota sandstone is the great water holder of the plains. The origin of the water has been assigned to three sources, viz.: Artesian flow from the mountains, sheet water, and local rainfall. Springs are everywhere present and constitute an important economic phase of the group.

61. Loc. cit., 18: 17.

The salt springs and marshes, which are found in northern Kansas and at Lincoln, Neb., obtain their flow from a bed of saliferous shales near the upper part of the formation.

The fossils consist of plants, invertebrates, and vertebrates. Of these, plants greatly predominate. Over 500 species are found in the group, of which more than ninety per cent. are dicotyledonous leaves. Shells are found in the lower parts of the group, while vertebrates are represented by impressions of bird tracks, a fossil turtle, and a reptilian vertebra.

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In presenting this bibliography of the literature of the Dakota Cretaceous of Kansas and Nebraska, the writer is by no means unmindful of the fact that it is of necessity incomplete. There are a number of references to the subject to which but vague allusions have been seen, and which up to the present time have been unavailable. Doubtless there are many more of which the writer has never heard. It is believed, however, that the greater part of the literature of the group is cited on the following pages. Ordinarily only such articles as have a direct bearing on the subject have been referred to, but occasionally a publication is mentioned which treats of the Dakota but incidentally; but in such cases it will be observed that the point referred to is pertinent to some phase of the subject.

The chronological order has been observed, in order to show more clearly the development of the subject; but an alphabetical index at the close will aid in locating any particular paper. Complete titles are given unless they are so long as to be unwieldy. In references to periodicals, abbreviations are used as much as possible. The abbreviations vol. and pp., however, are usually omitted, and a colon is used to separate volume and page; thus: *Proceedings of the Philadelphia Academy of Science*, volume VIII, pages 26 to 38, is written: *Proc. Phila. Acad. Sci.*, 8: 26-38. The dates under which the articles are arranged are those of the year of publication as indicated by the title-page.

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2. Lewis, Meriwether, and Clarke, William. *Expedition up the Missouri River, and across the American Continent to the Pacific Ocean*, 1: 42-51.

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5. Fremont, J. C. *A Report on the Exploration of the Country between the Missouri River and the Rocky Mountains, etc.* Senate document No. 243, 3d session, 27th congress, p. 12.

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